DEVELOPMENT OF A PROTOTYPE ASSESSMENT TOOL TO EVALUATE THE POTENTIAL TO SUCCESSFULLY IMPLEMENT DECONSTRUCTION AS A REGIONAL WASTE REDUCTION STRATEGY

BY

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This dissertation is dedicated to my family and past generations: those whom sacrificed, endured, fought, and persevered so that the opportunities I have could exist today.

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Abstract of Dissertation Presented to the Graduate School
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DEVELOPMENT OF A PROTOTYPE ASSESSMENT TOOL TO EVALUATE THE POTENTIAL TO SUCCESSFULLY IMPLEMENT DECONSTRUCTION AS A REGIONAL WASTE REDUCTION STRATEGY

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Chairman: Charles R. Glagola
Major Department: Civil and Coastal Engineering

The construction industry produces one-third of the nation's annual waste stream. This accounts for an estimated 136 million of the 395 million tons of waste produced annually. Our expanding national infrastructure is a result of increasing population and a strong stable economy. Unfortunately, the development needed to support the growing nation is occurring unsustainably. Developing in an unsustainable manner has significant detrimental global environmental impacts. Replacing environmentally detrimental practices with sustainable alternatives assists in ensuring that future generations have an equal or better quality of life.

A prototype assessment tool was developed through this research that identifies, assembles, and evaluates regional factors allowing a user to determine their regions' potential to successfully implement deconstruction as a waste reduction strategy. The assessment tool targets entities that are responsible for solid waste management and provides them with a means to determine if deconstruction could be an effective strategy to reduce the waste stream generated from single family residential demolitions and renovations. The assessment tool calculates 1) the Deconstruction Implementation Potential Score, 2) the Deconstruction Implementation Potential Ranking, 3) the Potential Waste Diversion Quantity, and 4) the Potential Waste Diversion Percentage. These scores can be used to determine if the region should pursue deconstruction as a waste reduction strategy or if the region should pursue other waste reduction alternatives. Based on the user input, the assessment tool also provides regionally specific recommendations to assist the user in improving the regions' potential to successfully implement deconstruction. Although this tool was developed to specifically address the residential deconstruction process, an additional, and possibly more significant impact is that this tool can also be used in the solid waste management strategic planning process to produce an overall deconstruction strategy.

The tool was distributed for review to four main categories of individuals: deconstruction experts, recycling coordinators, government and regulatory agencies, and private entities. Each group was targeted due to its unique ability to provide input on several aspects of the assessment tool. Through this distribution and review, the necessity and usability of this tool were validated.

CHAPTER 1
INTRODUCTION

Contribution

This research provides a unique approach for analyzing a region's potential for the successful implementation of deconstruction as a waste reduction strategy. This research focuses on reducing the waste generated from single-family residential renovations and demolitions. A prototype assessment tool was developed that identifies and evaluates factors specific to the regional implementation of deconstruction. The assessment tool was designed to accommodate future expansion to include other residential structure types, commercial structures and industrial structures. The development of this assessment tool determines the deconstruction potential in a given region and provides regionally specific recommendations to improve the region's potential to successfully implement deconstruction.

Problem Statement

The construction industry produces one-third of the nation's annual waste stream. This accounts for an estimated 136 million of the 395 million tons of waste produced annually (Franklin Associates, 1998). Our expanding national infrastructure is a result of increasing population and a strong stable economy. Unfortunately, the development needed to support the growing nation is occurring unsustainably. Unsustainable development has significant detrimental global environmental impacts. Replacing environmentally detrimental practices with sustainable alternatives assists in ensuring that future generations have an equal or better quality of life.

Unsustainable practices occur at all stages of the construction process, from the over-mining of raw minerals for the production of construction materials to the ultimate wasteful disposal of these materials in construction and demolition landfills. It is possible to implement sustainable practices in all aspects of the construction industry. Practices such as recycling and reuse can reduce the demand for virgin materials, traditional construction techniques can be replaced with environmentally friendly building techniques, and alternatives to landfilling can be employed to reduce the waste stream resulting from construction industry activities. No other single industry accounts for one third of the nation's annual waste stream. Targeting the construction and demolition (C&D) waste stream for reduction can reclaim reusable and valuable resources, assist in implementing an improved recycling effort, and reduce the rate of rapidly decreasing landfill space.

The traditional symbol of recycling is well known. A triangle containing the words "reduce," "reuse" and "recycle." This symbol represents the concept of closing the loop, the process of reusing materials over and over. The same closing the loop concept can be used to show how this research can assist in creating a closed loop with traditional demolition and renovation waste. Data are available on the magnitude of the waste stream produced by the construction industry. Case study data show that deconstruction is an alternative to traditional demolition that can divert materials from the waste stream. The missing portion needed to close the loop is a tool to determine if deconstruction can be successfully implemented to reduce the C&D waste stream. Figure

1.1 illustrates the problem of the waste generated by the construction industry, one potential solution found in the process of deconstruction and the current missing link of implementing the deconstruction process.

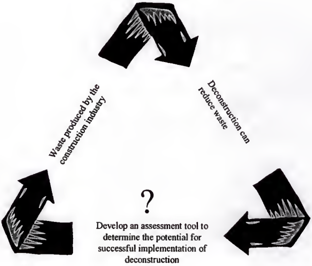

Waste produced by the construction industry
Deconstruction can reduce waste
?
Develop an assessment tool to determine the potential for successful implementation of deconstruction

Figure 1.1 Closing the Loop on Implementing Deconstruction.

If waste reduction is established as a priority in the region, the first step is determining what options are available to reduce the waste stream. One option is implementing the deconstruction process. Determining the potential for success of each waste reduction strategy can assist regional authorities, such as solid waste managers, in determining the best programs to support, fund and implement. The prototype Deconstruction Implementation Assessment Tool (DIAT) provides the region with a Deconstruction Implementation Assessment Ranking (DIAR) and regionally specific recommendations to allow the user to determine if deconstruction would prove to be a successful waste reduction option in the region. In regions showing a high potential for success the tool can provide the individuals requesting funds with supporting information and suggestions to pursue program implementation.

Hypothesis

A prototype assessment tool can be developed that addresses the constraints to implementing deconstruction and can, through the identification and evaluation of influence factors and variables, provide a deconstruction implementation score that reveals the potential for successful implementation of deconstruction as a waste reduction strategy on a regional level.

Deconstruction Defined

Deconstruction–defined as the whole or partial disassembly of structures for the purpose of reclaiming the maximum quantity of building components and materials for reuse or recycling–can significantly reduce the waste stream produced by the construction industry (by dEsign, 1997; Cook, 1997; Joslin et al., 1993; Kreitner, 1996; Leroux and Seldman, 1999; NAHB, 1997). Deconstruction is a new term used to describe an old process–the selective dismantlement or removal of materials from buildings as an alternative to demolition. The primary intent is to divert the maximum amount of building materials from the waste stream. Top priority is placed on the direct reuse of salvaged materials in new or existing structures. Immediate reuse allows the materials to retain their highest economic value.

Research Objectives and Scope

Objectives

The overall objective of this research project is to develop a prototype assessment tool that allows a user to evaluate a region's potential to successfully implement deconstruction as a waste reduction strategy. The assessment tool targets entities that are responsible for solid waste management and is intended to provide them with a means to analyze their region to determine if deconstruction could be an effective strategy to reduce the waste stream generated from single family residential demolitions and renovations.

Objective 1

Determine the (a) magnitude of the national C&D waste stream and (b) isolate the residential demolition and renovation quantities to (c) determine the potential waste reduction quantity that implementing deconstruction could have on the national waste stream.

Objective 2

Deconstruct several wood frame single-family residential structures to validate existing case study deconstruction data and to add to the deconstruction data available for analysis.

Objective 3

Determine the types and quantities of materials that may be diverted from the waste stream by deconstructing wood frame single-family residential structures.

Objective 4

Identify variables and influence factors affecting the success and implementation of deconstruction.

Objective 5

Develop a prototype deconstruction implementation assessment tool by isolating and quantifying selected variables specific to regional deconstruction implementation.

Objective 6

Validate the prototype assessment tool through reviews by deconstruction experts, solid waste managers, and government or regulatory agencies.

Objective 7

Provide recommendations for implementing sustainable waste management practices such as deconstruction on a long-term basis.

Scope

The input data for development of the prototype assessment tool is limited to single family wood frame deconstruction data. Case studies exist that provide data from waste streams generated from commercial structures as well as other residential construction types. In order to validate these data for use in the assessment tool, a regional data set derived from the deconstruction of several single-family wood frame homes was used. These homes provided a data source to verify the national and international case study data collected on the types of materials recovered, the quantity of materials recovered, and the waste diversion rates achieved.

The assessment tool will not consider factors used to determine specific structures' potential as a cost effective project for deconstruction nor will it address factors affecting a contractor's decision to use deconstruction on a specific structure. This prototype assessment tool addresses the large-scale implementation or mandating of the deconstruction process on a regional level. If this were the case all structures would be considered for deconstruction and all contractors would have the same competitive disadvantage until the deconstruction process was proven cost effective.

Research Methodology

The source of information and data collected for this research project came from three funded projects at the University of Florida, M.E. Rinker Sr. School of Building Construction, Center for Construction and Environment. The first project was funded by the Florida Center for Solid and Hazardous Waste Management (FCSHWM), and focused on the compilation of existing data on deconstruction. The second project was a Department of Environmental Protection (DEP) grant that focused on data collection resulting from the physical deconstruction of six homes in the Gainesville Florida area. The third project was funded by the Environmental Protection Agency/Jobs Through Recycling (EPA/JTR) grant and focused on training and creating a building assessment model for deconstruction.

Phase 1 Literature Review.

The initial phase of this research was dedicated to reviewing literature on the waste produced by the construction industry. Waste data from international, national and state sources were collected and analyzed to determine the magnitude of the waste stream generated by the construction industry. The national C&D waste stream is comprised of 3 main categories: construction waste, renovation waste, and demolition waste. Since the deconstruction process impacts only the renovation and demolition waste streams, it was necessary to isolate the quantities generated from these sectors. In addition, due to research funding and the structures available for data collection the residential waste quantities had to be isolated from non-residential waste quantities.

After determining the total waste stream resulting from residential demolition and renovation a review and analysis of national and international deconstruction case studies was conducted. Data were collected to determine the potential impact that implementing deconstruction could have on reducing the total C&D waste stream. Case studies provided information regarding both the quantities and quality of materials salvaged from previous deconstruction projects. Additionally, this review of case studies assisted in developing a preliminary list of factors influencing the deconstruction process.

Phase 2 Deconstruction Data Collection

Six single-family wood frame residences were deconstructed to determine the types and quantities of materials that could be salvaged for reuse or recycling. This data complimented the international and domestic case study data. The case study data and data collected from the six test area deconstructions were used to determine the expected waste diversion rate attainable by implementing deconstruction. This diversion rate was needed as input for the assessment tool.

The physical deconstructions provided valuable information identifying additional qualitative and quantitative variables affecting the deconstruction process. Factors affecting the success of deconstruction as a waste reduction strategy were also identified.

Phase 3 Isolation and Refining Variables

The information collected in Phases 1 and 2 was further analyzed to assist in refining the list of key variables and influence factors affecting deconstruction. The test-area deconstructions were used to expand and validate both qualitative and quantitative variables associated with the deconstruction process. The fundamental objective of this research was to develop an assessment tool for regions seeking to reduce their C&D waste stream. The tool will be used to determine the potential deconstruction has to be implemented successfully as a waste reduction strategy. The original list of variables and influence factors were separated into the following three categories.

1. Independent variables
2. Location dependent variables
3. Structure dependent variables

The assessment tool was developed from the standpoint of individuals or entities responsible for the regional management of C&D waste. It is important to note while refining the list of variables items specifically affecting deconstruction contractors or individual structures were not considered. This tool addresses the regional factors of affecting a full scale implementation of deconstruction to reduce the C&D waste stream.

Phase 4 Deconstruction implementation assessment tool

The information collected and analyzed from Phases 1 through 3 provides the input and basis for the development of the Deconstruction Implementation Assessment Tool. The variables chosen were divided into 6 sections.

1. Regional and Economic Growth
2. Development Patterns
3. Business Infrastructure
4. Available Building Stock
5. Policy and Incentives
6. Waste Quantities

The assessment tool was built in Microsoft Excel and is driven by macros. The tool requires user input based on the variables and influence factors; it then calculates and reports the Deconstruction Implementation Potential Score (DIPS), the Deconstruction Implementation Ranking (out of 100), the potential waste diversion quantity, and the potential waste diversion percentage. The prototype assessment tool was sent to solid waste professionals for their review and input.

Phase 6 Assessment Tool Review

The assessment tool was distributed for review to four categories of individuals. These individuals received a presentation introducing deconstruction and providing instructions for the assessment tool, and a questionnaire or survey. Each group were targeted to provide the needed feedback to validate the assessment tool.

1. Deconstruction experts
2. Recycling coordinators/solid waste managers
3. Government/regulatory agencies
4. Private entities interested in sustainable practices

Each group's feedback and input was used to refine the assessment tool for future use.

Phase 7 Conclusion and Recommendations

Results from the total research effort, assessment tool, and reviewer's input were used to develop an implementation strategy and the recommendations for a strategic waste reduction plan.

Summary

The objectives and phases of the research methodology combine to create a research plan for the completion of this project. These steps are presented in outline form in Figure 1.2.

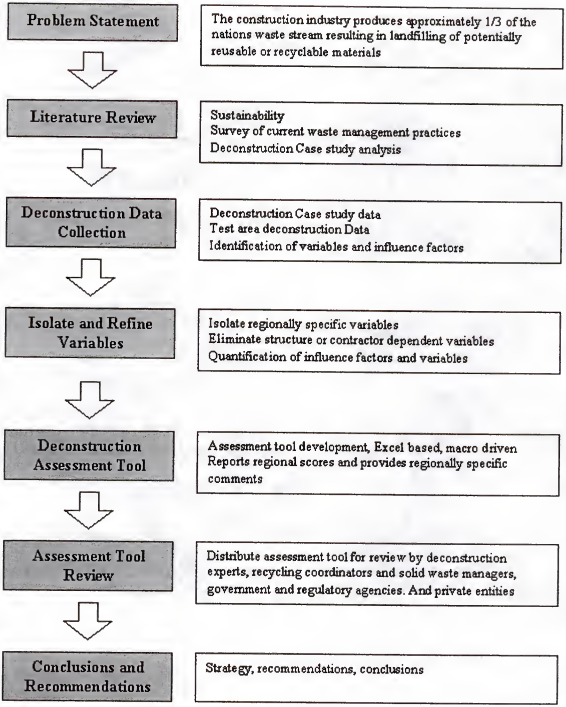

Problem Statement
The construction industry produces approximately 1/3 of the nations waste stream resulting in landfilling of potentially reusable or recyclable materials
Literature Review
Sustainability
Survey of current waste management practices
Deconstruction Case study analysis
Deconstruction Data Collection
Deconstruction Case study data
Test area deconstruction Data
Identification of variables and influence factors
Isolate and Refine Variables
Isolate regionally specific variables
Eliminate structure or contractor dependent variables
Quantification of influence factors and variables
Deconstruction Assessment Tool
Assessment tool development, Excel based, macro driven
Reports regional scores and provides regionally specific comments
Assessment Tool Review
Distribute assessment tool for review by deconstruction experts, recycling coordinators and solid waste managers, government and regulatory agencies. And private entities
Conclusions and Recommendations
Strategy, recommendations, conclusions

Figure 1.2 Objective, Phases, and Research Methodology.

CHAPTER 2
BACKGROUND

Introduction

The background issues supporting this research effort are immense. Narrowing the focus of this research to a specific, useful, and individual project was in itself a challenge. This chapter is intended to introduce general principals regarding sustainability and the construction industry's impact, existing and potential, on the sustainability effort. To understand the ultimate focus of this research it is necessary to begin narrowing the scope of the concept of sustainability to an inner circle of sustainable construction and demolition waste management. This chapter provides information on sustainability and the construction industry, the magnitude of the waste stream generated from this industry, international and domestic policies and incentives regarding construction and demolition waste management, and the current waste management practices.

Sustainability

Before discussing the concept and principles surrounding sustainability, it is necessary first to clarify the meaning and magnitude of this concept. Sustainability is an all-inclusive term that defines a goal that can be achieved through many smaller sustainable efforts.

> The goal of sustainability is to guide the economic and social forces of the earth's nations to live within the goods and services provided by ecosystems and naturally occurring sources of energy (solar, geothermal, tidal) without reducing the availability of these goods, services, and energy sources for future generations. (Kibert, 1999, p.19)

Sustainability encompasses all social, environmental and economic activities from clean air and water to preserving and protecting natural systems to advancing educational systems to human equality. Within the outer global shell of sustainability (see Figure 2.1), lies one component that can assist in achieving the goal of sustainability and that is sustainable development. An aspect of sustainable development is to adopt sustainable construction practices. One major concept of the construction industry is the construction and demolition waste produced. Adopting a sustainable method of managing this waste would assist in the movement toward sustainability.

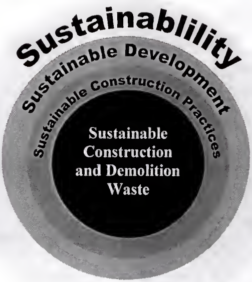

Sustainability
Sustainable Development
Sustainable Construction Practices
Sustainable Construction and Demolition Waste

Figure 2.1 Sustainability Layers.

Historically, industrialized nations have grown and advanced technologically while often disregarding the environment. One important component of sustainability is to develop and grow in a sustainable manner, often referred to as sustainable development. Sustainable development, in general terms, may be defined as meeting the needs of the present without compromising the ability of future generations to meet their needs. The development that occurs on local, regional, and national levels plays a key role in society's sustainability. Local or regional developments must occur in a sustainable manner or the ultimate goal of sustainability can not be achieved.

A subset of the concept of sustainable development is sustainable construction practices. The construction industry, the structures it creates or removes and the products developed to support and supply the industry have significant global impacts. In the United States, buildings represent more than 50% of the nation's wealth. New construction and renovation account for approximately $800 billion or approximately 13% of the Gross Domestic Product and employ over 10 million people (Public Technoligy Inc., 1997). The construction industry uses 40% of all extracted materials. Thirty percent of all energy used is a result of the construction industry and the built environment (Franklin Associates, 1998).

A subset of the construction process is the practice of managing the waste produced by these activities in a sustainable manner. Out of the 395 million tons of waste produced nationally, 136 million tons are a result of construction and demolition waste. Over 34% of our nation's waste is produced by a single sector of the economy, the construction industry. Approximately 7 pounds of waste are produced for every square foot of new construction. Renovation and demolition can produce up to 70 pounds of waste per square foot depending on the structure type and demolition technique (Hanrahan, 1994). Buildings are constructed and, on average, are demolished twenty-eight years later (Bohlen, 1997). Unfortunately traditional mechanical demolition leaves piles of mixed debris that are, in general, ultimately landfilled (Lerner, 1997). The construction industry lags far behind other industries in efficiency related to materials consumption, reuse, and recycling. For example, a new automobile such as the BMW contains 70 percent recycled content, but a new building probably contains less than 1 percent reclaimed materials (Stamcampiano, 1999). Other industries have learned the benefits of optimizing procedures; the construction industry however remains somewhat resistant to change.

The total economic and environmental impact of the construction industry begins with raw material extraction and continues on with product manufacturing, product transportation, building design and construction, operations and maintenance, and building reuse or disposal. Each building product has an intrinsic value in the form of energy, the energy used to extract the raw materials, process the materials, create a marketable product, distribute the product, and finally transport the product for use. This intrinsic energy value is often referred to as the materials embodied energy (Malin, 1993). Extraction of these natural resources, especially through mining and smelting, is one of the most wasteful, energy intensive and polluting industries on earth (Kibert and Languell, 2000). Reusing and recycling building materials prevents this pollution by reducing the need for mining virgin natural resources. When considering the combined energy required to transport materials and the labor required to design and construct buildings, demolishing a structure is simply throwing away many valuable resources. Reusing building materials conserves this energy "embodied" in the products.

National C&D Waste

Quantities and Components

As previously stated, 136 of the 395 million tons of waste generated in 1996 were a result of the construction industry. Three main construction industry activities account for this waste stream: demolition, renovation, and new construction. Figure 2.2 illustrates the national quantity of C&D waste and the corresponding component breakdown.

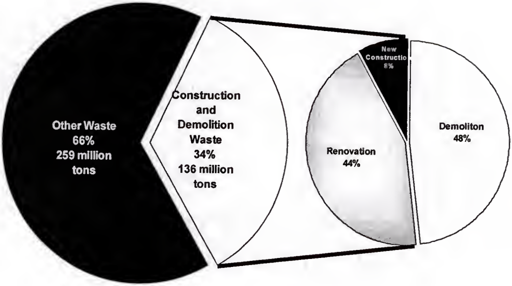


Figure 2.2 National Waste Quantities and C&D Component Breakdown (Franklin Associates, 1998).

These percentages correspond to 65 million tons (48 %) of demolition waste, 60 million tons (44 %) of renovation waste and 11 million tons (8 %) of new construction waste. Ninety-two percent of the construction industry waste stream can be attributed to demolition and renovation activities. These waste streams can be reduced significantly by the implementation of deconstruction. Only 8% of the waste stream is a result of new construction activities (Franklin Associates, 1998).

The deconstruction process will not have a significant direct impact on the waste generated from the new construction market sector. The waste stream targeted is that generated by the demolition and renovation sectors. These two activities combined comprise 125 of the 136 million tons of waste.

The demolition and renovation portions of the waste stream can be directly impacted-reduced-by deconstruction (by design, 1997; Center for Economic Conversion, 1997; Holmes, 1997; Joslin et al., 1993; Leroux and Seldman, 1999; NAHB, 1997; Public Technology Inc., 1997). Renovation requires partial or complete removal of the interior and possibly exterior of the structure prior to the renovation/new construction that occurs to renew the structure. During the "rip out" stage of renovation deconstruction could significantly reduce waste. Targeting the demolition and renovation waste stream provides the greatest potential impact for reducing the amount of usable building materials that are commonly sent to landfills (Joslin et al., 1993). Since these activities account for the majority of the C&D waste, the focus should be on providing alternatives to the traditional demolition process. Both demolition and renovation provide opportunities for material recovery, reuse and recycling by means of deconstruction.

Environmental Policy

There are very few policies in place on a national level that mandate environmentally friendly construction practices, buildings, designs, and materials. Without policy favoring sustainability, researchers looking for ways to influence sound environmental practices must look to the governments to offer incentives that will begin to sway the construction industry decision makers when designing and building for the future. Currently there are few incentives, and those that are offered are not nearly enough to persuade highly competitive businesses to invest the extra money in replacing traditional process with those designed to protect the environment. The US Environmental Protection Agency (EPA) runs a program that started in 1992 called Design for the Environment. This program forms voluntary partnerships with industry, universities, research institutions, public interest groups, and other government agencies (Kraft and Vig, 1997). The program attempts to influence current business practices and to reach people and industries that have the power to make major design and engineering changes. Their ultimate goal is to incorporate environmental considerations into the traditional business decision-making process. Designing for the environment is an important consideration for sustainability because it addresses the problem at the source. One of the greatest challenges faced by the deconstruction process is that design practices do not take into account the ultimate removal of the structure. When architects and engineers design structures and contractors build them it is with a sense of permanence. In reality, however, it is known that very few structures last forever.

The US Department of Energy, Office of Pollution Prevention, has begun a Pollution Prevention by Design project in an attempt to help engineers, designers, and planners incorporate pollution prevention strategies into the design of new products, processes, and facilities (Kraft and Vig, 1997). The problem facing the industry is not the invention or innovation, but the education and implementation of new techniques and concepts.

Existing Federal Laws and Executive Orders which pertain to the construction industry are primarily focused on energy conservation. The following is a listing of these regulations in place (Sustainable Systems Inc., 1994):

- Energy Policy and Conservation Act (EPCA of 1975)
- Resource Conservation and Recovery Act (RCRA of 1976)
- National Energy Conservation Policy Act (NECPA of 1978)
- Comprehensive Omnibus Budget Reconciliation Act (COBRA of 1985)
- Federal Energy Management Improvement Act (FEMIA of 1988)
- Energy Policy Act (EPACT of 1992)
- Executive Memorandum ("Environmentally and Economically Beneficial Practices on Federal Landscaped Grounds")
- 10CFR435
- 10CFR436
- Executive Orders: 12759, 12843, 12844, 12845, 12856, 12873, 12902

Over the past two decades, public concern and support for environmental protection have risen significantly spurring the development of an expansive array of new policies that substantially increased the government's responsibilities for the environment and natural resources (Kraft and Vig, 1997). The implementation of these policies, however, has been far more difficult and controversial. Government is an important player in the environmental arena, but it cannot pursue forceful initiatives unless the public supports such action. Ultimately society's values will fuel the government's response to a rapidly changing world-environment that will involve severe economic and social dislocations in the future. Environmental policy is difficult to predict, the U.S. must move from a nation that exploited resources without concern for the future to one that embraces sustainability to maintain the quality of life for present and future generations. If "green" plans were proposed in the US, they would survive the political process (Johnson, 1996). Several states have already implemented their own progressive environmental policies that are stricter than Federal regulations.

Incentives

Two major changes in federal policy are also creating major opportunities for deconstruction: the demolition of public housing under the HOPE VI programs and the conversion of closed military bases across the US (Leroux and Seldman, 1999). Deconstruction relies on a source of structures available for removal. If deconstruction were employed in conjunction with demolition to remove public housing across the country, as well as other public and private sector structures, communities could significantly decrease the waste generated in their region. Implementing deconstruction can assist communities in reaching environmental, economic, and social benefits for their residents at little or no additional cost compared to traditional demolition (Self Reliance Inc., 1998).

Forty-four states and the District of Columbia have set solid waste diversion and/or recycling goals (FDEP, 1998). Figure 2.3 shows the states, their recycling goal, and the deadline to reach the goal. The chart, depending on the state, indicates recycling or waste reduction goals. The recycling or reduction percentages range from 20% to 60%. State deadlines range from as early as 1992 in Louisiana to 2010 in West Virginia.

Several states are beginning to insist on environmental preservation. Blatant disregard for the environment is no longer tolerated. An example of a progressive environmental organization is the California Resource Recovery Association. This organization is actively pursuing manufacturer responsibility legislation (CIWMB, 1997). The principles the association wishes to incorporate into the legislation follow:

The California Resource Recovery Association

- If it can not be assimilated into the environment, then it can only be leased
- Anything not biodegradable/recyclable is tagged with its constituents and manufacturer
- Mandated a deposit laws for certain materials
- Require mandatory separation of wastes
- Require mandatory procurement of recycling products for public projects
- Require "advanced disposal fees" for manufacturer wastes
- Advanced fees mean that disposal is calculated upfront as part of the costs of producing the product and is internalized by the company.
- This is like pollution permits, whereby quotas could be traded between those with product stewardship and those without, this would be called a "processing fee"
- Eco-labeling and materials labeling is consistent.
- Product made with minimum recycled content requirements.

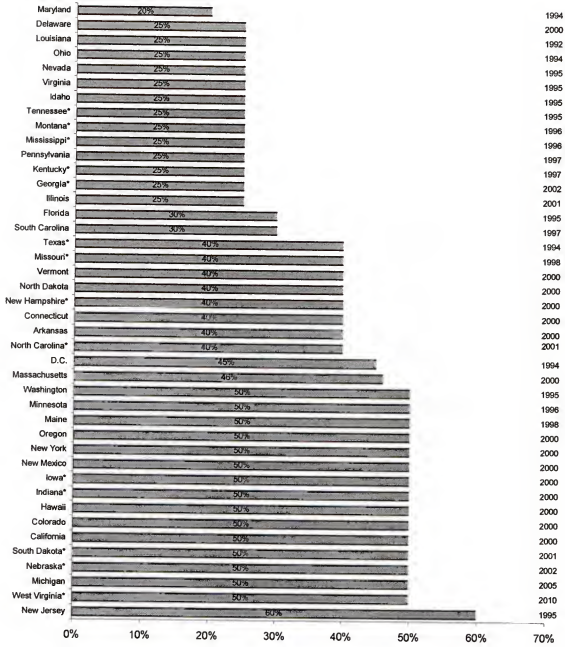


Figure 2.3 State Recycling/Waste Reduction Goals and Deadlines (FDEP, 1998) * Indicate waste reduction rather than recycling goals.

Although not specifically related to the demolition of structures the California Resource Recovery Association shows a commitment to implementing environmentally friendly manufacturing practices. Government and the public tends to associate incentives with money. Although this is often the case it is not the only way to provide incentives. Incentives may come in the form of disincentives or penalties for excess disposal quantities. By creating an environment not conducive to wasteful practices an incentive is created to waste less.

International C&D Waste Quantities and Policy

Many other countries face similar C&D waste stream dilemmas. The world as a whole is growing, and as such, countries are expanding, developing, and generating C&D waste. Most countries have similar rates of C&D waste generation, disposal options and the desire to achieve a more sustainable environment. Common key factors in the international progress of the deconstruction implementation effort include; the status of government involvement, the magnitude of the C&D waste stream, the building types (construction materials), and the availability of disposal options.

Australia

To date Australia has only conducted scattered and small research studies regarding their construction and demolition waste stream. Due to this lack of research information there is no comprehensive understanding of the quantities and types of demolition waste generated or recycling capabilities (Crowther, 2000). The numbers available indicate Australia has a total waste stream of 14 million tons per year (Reddrop and Ryan, 1997). Although the actual quantity of C&D waste is unknown, it is estimated at 16%-40% of the 14 million tons of waste (Bell, 1998; Craven, 1994). Using these figures, the C&D waste stream for Australia lies between 2.24 million and 5.6 million tons per year.

In Victoria, the C&D waste stream has been categorized into 74.6% demolition waste, 21.1% construction waste, and 4.3% classified as other (EcoRecycle Victoria, 2000). Sydney has estimated 43% of its C&D waste stream to be demolition-related

(Lawson, 1994). Due to the large quantities of waste generated from the construction industry (up to 40%), Australia has specifically targeted this waste stream for reduction. Table 2.1 shows a summarized list of State/Territory legislation and Policy.

Table 2.1 Australian Legislation and Policy.

State/Territory	Legislation	Policy
Commonwealth	National Heritage Trust of Australia Act of 1997 National Environmental Protection Measures (Implementation) Act 1998 Environmental Protection and Biodiversity Conservation Act 1999	Waste Management Awareness Program National heritage Trust – Waste Wise Construction Program Building Code of Australia
Australian Capital Territory	Environmental Protection Act 1997	No Waste by 2010 strategy Development Control Code for Best Practice Waste Management in the ACT 1999
New South Wales	Waste Minimization and Management Act 1995 Protection of the Environment Operations Act 1997	Construction and Demolition Waste Action Plan 1998 Waste Planning and Management Fund Waste Reduction and Purchasing Policy – A Guide for Agencies 1997 Waste Education Strategic Directions Statement 2000 – 2002.
Northern Territory	Waste Management and Pollution Control Act 1989 Environmental Assessment Act 1994	Waste Management and Pollution Control Strategy 1995
Queensland	Environmental Protection Act 1994	Waste Management Strategy for Queensland 1996
South Australia	Environmental Protection Act 1993	Environmental Protection (Waste Management) Policy 1994 (Draft) Environmental Protection (Waste Reduction, Recycling and Disposal) Policy 1999
Tasmania	Environmental Management and Pollution Control Act 1994 Land Use Planning and Approvals Act 1993 Environmental Protection (Waste Disposal) Regulations 1974	None available
Victoria	Environment Protection Act 1970 Environmental Protection (Amendment) Act 1996	Becoming Waste Wise Education Program EcoRecycle Victoria
Western Australia	Environmental Protection Amendment Act 1998 Environmental Protection (Landfill) Levy Act 1998	WA Waste Reduction and Recycling Policy Waste Management and Recycling Fund

Australia, as with most countries, shows the variability in regional C&D waste quantities as well as programs to control and reduce the waste. Two common practices in Australia are the deconstruction of homes for reuse and moving homes to new locations. The country's general focus is waste minimization and designing for the environment.

Germany

It is estimated that the demolition portion of the German waste stream is 45 million tons per year (Schultmann and Rentz, 2000). Germany is far advanced in laws and procedures regarding construction and demolition waste management. Advanced recycling technology, planning, and processes have resulted in successful efforts in waste minimization. Germany is concentrating their current research efforts on creating an assessment tool to determine the cost of deconstructing versus demolition for individual structures.

Israel

Construction waste accounts for 350,000 to 700,000 tons of waste per year. This is an estimated 60% of the solid waste generated-excluding household waste-in Israel each year (Katz, 2000). It is reported that the majority of this waste is a result of the construction process versus the demolition of structures. The majority of the structures in Israel are reinforced concrete. This structure type is difficult to deconstruct and must often will be demolished. Research efforts in Israel are concentrating on the design process creating module structures that will be designed for deconstruction. They have achieved success in constructing and deconstructing parking garages and military structures.

Japan

Construction waste comprises 20% of Japan's industrial waste category (Futaki, 2000). Japan has many laws in place concerning waste disposal and public cleanliness governing the removal of structures. Although Japan has advanced technology in recycling, this technology does not extend greatly into the construction sector. The major construction types in Japan are concrete and steel which lends itself more to recycling than reuse. Unfortunately, 90% of Japan's illegal dumping is composed on construction debris (Futaki, 2000). The steel and concrete construction types and illegal dumping have prompted more focused efforts on advancing recycling technology for the construction industry.

Netherlands

As in the United States, the largest single waste stream in the Netherlands is construction and demolition waste. Approximately 72.36% of this waste is a result of demolition activities (Koen et al., 2000). The Netherlands produces approximately 15 million tons of construction and demolition waste annually (Pietersen, 1993). The quantity of construction and demolition waste generated exceeds the country's municipal solid waste. In order to combat the C&D waste stream the Dutch Government passed a law in January 1996, which states: "dumping of reusable building waste is prohibited". In 1997, the Dutch government passed a law prohibiting the dumping of reusable building waste (Noord, 1998). This ban prohibits the landfilling of reusable or burnable construction and demolition waste. The Landfill Ban was an important instrument to promote waste reuse and increase the reuse rate. In addition to the landfill ban, the *Implementation Plan for Demolition and Construction Wastes* sets objectives that reuse should reach approximately 90% and in the year 2000 no more than 10% of construction and demolition waste should be landfilled or incinerated (Kowalczyk et al.). Currently, this law is responsible for the astounding reuse rate achieved by the construction industry, approximately 90% or 13.5 million tons of this waste are reused (Koen et al., 2000). In addition to reusing their own waste, the construction industry uses approximately 11.5 million tons of wastes generated from other industries. The Netherlands has found that prevention and reuse are unlikely to grow if purely left up to the market forces. The Government in the Netherlands aims to direct the construction and demolition waste markets through legislation and other forms of regulations. The primary role of government is to set the constraints and establish related policies.

The primary construction type, reinforced concrete, inhibits the reuse efforts in the Netherlands. Reinforced concrete is difficult to disassemble for immediate reuse. It is also not cost effective to recover for reuse purposes. The low cost of new materials contributes to the lack of monetary incentive to recover materials. Although these are key issues faced by all nations attempting to implement deconstruction, the Netherlands have achieved one of the highest reuse percentages. The Netherlands is at the forefront of machinery invention to assist in the deconstruction effort (Dorsthorst et al., 1999; Noord et al., 1998). The majority of these processes and tools concentrate of disassembling concrete structures. They are currently concentrating their research efforts on designing structures for disassembly to assist in the deconstruction process (Koen et al., 2000).

In the Netherlands, waste disposal is primarily organized at the provincial levels. The Government of the Netherlands acts in a similar manner to the US government. The Federal government sets standards and the state and local governments must meet a minimum of this standard. In the Netherlands, the Provinces can include regulations in their Provincial Environmental Ordinances to implement their Provincial Environmental Policy Plans. The Provinces can establish environmental policies that are stricter than the general environmental policies of the Central government. Similarly, in the US, state regulations are often more stringent than the federal regulations.

Norway

The total C&D waste stream in Norway is approximately 1.5 million tons per year. Approximately 65% of this waste can be attributed to the demolition of structures. Norway generates an additional 22 million tons of waste from the construction of bridges, ports, roads, railroads and airports (Myhre, 2000). Norway faces many challenges to implementing deconstruction due to a lack of a market for salvaged goods, sparse population, transportation distances, and low land cost making disposal more economical than reuse and recycling.

United Kingdom

The UK as a whole produces approximately 53 million tons of C&D waste each year. It is estimated that 24 million tons of this C&D waste is currently recycled (McGrath et al., 2000). The UK can directly attribute the increase in recycling to the introduction of a landfill tax in 1996. The number of recycling sites rose from 100 in 1994 to over 400 sites currently. The UK is faced with the increasing cost of landfilling and stricter regulations governing the disposal of recyclable materials (Centre for Waste and Recycling, .

In England, approximately one sixth of the total waste is a result of construction and demolition as stated in *Rethinking Construction,* a report produced by Sir John Egan's Construction Task Force 17 for the Deputy Prime Minister. This report aims at increasing efficiency through more sustainable business practices. The Task Force recommendations will enable the construction industry to work toward improving performance and sustainability. The Government is also working closely with representatives in the industry to develop a strategy for achieving more sustainable construction. A Sustainable Construction Action Group reports to the Government Construction Clients' Panel on how Government can initiate in adopting better principles of sustainability in its procurement, operation of buildings, and other built assets.

The Construction Best Practice Program is intended to promote the strategies of waste reduction, use of recycled materials, and whole life costing. Industry plans to establish a Sustainable Construction Industry Focus Group to encourage the necessary market transformation within the construction industry.

An example of an England government policy on the use of construction and demolition waste aggregates as stated in *Minerals Planning Guidance Note 6*, published in April 1994. "Aggregates and products made from aggregates should be recycled wherever possible and where technically, economically and environmentally acceptable, **construction and demolition wastes should be used instead of primary materials.**"

The waste, demolition, and aggregate industries have responded positively to the policy of encouraging the use of recycled materials. The structure of the recycling industry is expanding and changing rapidly, spurred on by the tighter waste regulation and the landfill tax. This enthusiasm is being captured in developing the industry strategy for more sustainable construction.

Canada

In Ontario, over 20% of waste currently heading to landfills is a result of the construction and demolition industry (by dEsign, 1997). The Ontario government recently passed Bill 102, a section of the "3 R's Regulations" made under the

Environmental Protection Act. The Bill puts increasing pressure on the construction industry to divert materials from the landfills. Ontario has established a target to decrease the amount of waste by at least 50% by the year 2000 (by dEsign, 1997).

In British Columbia, landfill tipping fees have doubled since 1989 and continue to rise. Contractors are required to submit a waste plan and two bid prices, one for demolition and one for deconstruction (Leroux and Seldman, 1999).

Summary

The following tables provide summary information as collected from the CIB report. Table 2.2 summarizes several countries waste quantities, current practices and waste management focuses while Table 2.3 shows C&D generation rates for several additional countries.

Table 2.2 International C&D Waste Information.

Country	C&D waste (Million tons)	Current Practices	Waste Management Focus
Australia	2.24 – 5.6	High rates of residential deconstruction	Waste minimization for construction Design for Disassembly
Germany	45	Laws Encourage Deconstruction Advanced C&D recycling	Building Assessment Model
Israel	0.35 – 0.70	Most structures reinforced concrete 60% of solid waste from new construction	Little Deconstruction due to construction type Design for Disassembly
Netherlands	14	80% + reused due to government regulations High recycling rate and advanced separation techniques	Design for Disassembly "Punching Unit" – for nail removal from wood
Norway	1.5	65.2% demolition related	Design for Disassembly BfO and ADISA (45 pieces)
UK	53 UK 180 Europe	28% Recycled or Reused 24 million tons recycled	NA
Japan	40%	Concrete and Steel construction Recycling Common	NA
U.S.	136	Recycling Construction Waste Management	Sustainable Construction Waste Reduction

Table 2.3 International C&D Generation Rates.

Country	Million tons of C&D waste per year
Norway	1.5
Belgium	7.5 – 8.0
Denmark	2.3 – 5.0
Finland	1.5
France	20 – 25
The Netherlands	13 – 14
Ireland	2.5
Italy	35 – 40
Luxenbourg	2.7
Spain	11 – 22
Great Britain	50 – 70
Sweden	1.2
Austria	52 – 120
Germany	22

Source: McGrath et al., 2000

Current Construction Industry Waste Management Practices

In the movement toward sustainability there are several changes occurring in the construction industry. For example, using "green" materials, designing and constructing more energy efficient structures, managing construction waste, and implementing reuse and deconstruction. As in most industries, the construction industry is driven by cost. The practices are well established and therefore the industry is resistant to change. When it comes to "debris" or "waste" the industry prefers the easiest, fastest, and seemingly most inexpensive option, which for the most of the nation is landfilling (Patrick Engineering Inc., 1997). In addition to resisting change in construction methods and disposal alternatives there is also a resistance to the concept of reuse. The common perceptions are that used materials are sub standard. These are some of the perceptions that must be changed – there are more sustainable waste management options, sources of materials, and construction techniques. This research addresses a sustainable alternative to traditional disposal options but first it is important to review current waste disposal options.

Landfilling

The most common practice in industry is to landfill materials perceived as waste. This practice occurs on all construction, demolition, and renovation sites. A 1994 survey done for the EPA identified about 1,900 active C&D landfills in the United States (Sustainable Systems, 1994). The state breakdown of the number of landfills is shown in Figure 2.4. In 1994, Florida was home to 277 landfills, in 1998 that number had dropped to 168 (FDEP, 1998).

Landfills have limited space and therefore can only receive a limited amount of waste. The large quantities of debris also contribute greatly to the cost increase felt by solid waste management. When one landfill reaches capacity, it must be replaced by a new landfill. In general, the cost to maintain an existing landfill is much less than closing the existing landfill and constructing a new one. The higher cost is a result of complying with environmental regulations, buying or allocating land, constructing the landfill, operating expenses, and long term maintenance costs after the landfill is closed. Additionally, the new landfill may be further away than the old landfill, increasing transportation cost (Public Technology Inc., 1997).

These costs can be avoided by keeping old landfills open. Closing landfills and the costs associated with this process are extraordinary. For example, the West Marin Sanitary Landfill in California expects its closing cost alone to be upward of $2.5 million. Landfill costs are ultimately passed on to society through tipping fees or taxes. No community welcomes the thought of having a new landfill built in their backyard. Keeping existing landfills operating as long as possible benefits both the environment and society (Townsend, 1998). In order to extend the longevity of the landfills waste reduction and recycling efforts must increase.

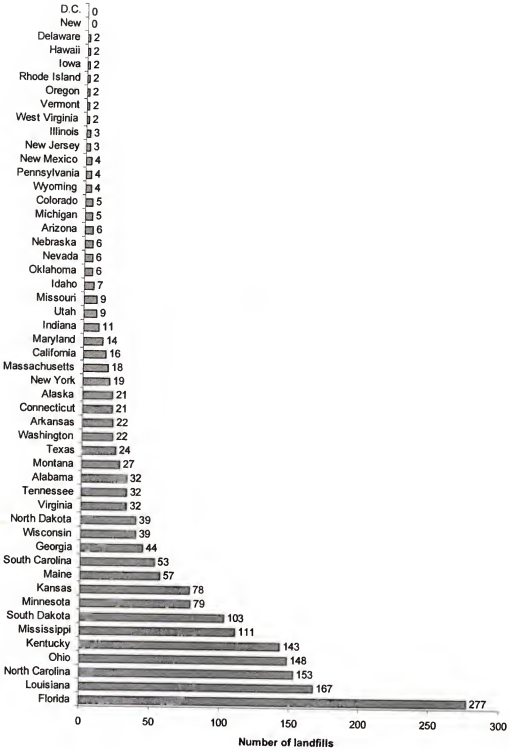


Figure 2.4 Number of C&D Debris Landfills in the United States (ERG List prepared for USEPA, September 30, 1994).

Renovation

Longevity is central to environmentally responsible building design (Cole, 1996). Longevity has two levels in the construction industry, first, longevity of the structure and second, longevity of the materials within the structure. Increasing longevity of a structure by designing for adaptability can significantly reduce the waste generated from demolished buildings (Levy, 1998). Longevity inherent to building materials allows for their reuse thus reducing waste sent to landfills. The common aim of both building and material longevity is to keep materials within the building cycle as long as possible avoiding disposal.

Adaptable building design makes altering the structure more appealing than simply demolishing structures for the needed land. Renovating is the ultimate reuse of a space, if done properly, few new materials are needed and the bulk of the structure remains intact (Hazen and Sawyer, 1993). Refurbishing older structures involves both the residential and commercial construction sectors. Large-scale renovations and adaptive reuse conversions are common in downtown and industrial areas. For example, in Canada's Quebec City, a church has been converted into condominiums; in Ottawa, a school into a regional building; in Toronto, the Bank of Montreal into the Hockey Hall of Fame; in Winnipeg, industrial buildings into seniors' housing; in Edmonton, the former Lieutenant Governor's mansion turned into a museum; and in Vancouver, offices were refitted for use by the University of British Columbia (Construction Waste Audits, 1999).

In many cases the adaptive reuse conversion option presents the most cost-effective and practical means to preserve historical buildings. Although renovation creates a potentially significant waste stream from the typical "gutting" of the interior of a building, if deconstruction were implemented, many materials would be salvaged, reused, and diverted from the waste stream. More importantly, considerably less demolition waste is created in renovation since the shell of the building remains intact.

Green Building Materials

Although green building materials are not a waste management option their popularity as part of the sustainability movement is worth addressing. The movement to "green" materials has begun as consumers find themselves more informed about environmental degradation. Green building materials are materials made from environmentally friendly components or manufacturing processes. Although green building materials may be designed for a present environmental benefit, they may not be the best materials for deconstruction or reuse. Green materials containing environmentally friendly materials may not be as durable and desirable as some traditional materials. On a sustainable level, there is a choice between using "green" materials in the construction of buildings and designing buildings as potential sources of future resources (raw materials) for new buildings. The ideal choices for deconstructable building materials are those with the greatest service life and those materials that are desirable or hold historical value. In order for the concept of deconstruction to be effective, it is necessary to use materials that will be in great demand in the future. For example, linoleum floor such as Marmoleum®, is made from renewable raw materials. The flooring contains linseed oil, wood and cork flours, natural rosins, crushed limestone, and non-toxic pigment (E Build Inc., 1997). This flooring is a much "greener" product than a traditional vinyl floor covering, however, although green it holds little future value. If a traditional solid wood tongue and groove floor was installed, the floor would last much longer and retain its value over time. The tongue and groove floor is worth salvaging, where as the linoleum floor is basically disposable. Although the wood floor is worth salvaging it is not usually thought of as a green product. However, if the wood is grown and harvested from a certified sustainably managed forest, the desirable wood floor can be a green product.

This process of selecting materials based on their durability and future desirability is part of the "design for deconstruction" concept. Selecting the best building and finish materials is not a simple task. Architects and designers currently face encyclopedia size books on building specifications, adding additional criteria without the proper working knowledge of the products would not prove effective.

Considerations must be given to energy and water efficiency, waste reduction, construction cost, building maintenance and management savings, insurance and liability, employee health and productivity, and building value (Public technology Inc., 1997). Materials are selected based on predetermined criteria. Adding reusability and deconstructability to the list of criteria will assist in the deconstruction effort as has been done in the Netherlands.

Demolition

The primary reasoning for demolishing structures is based on the needs of society's supply and demand. There is ultimately a demand for the structure to be removed. This demand can be a result of a need for the land an existing building occupies, the building may no longer serve any of society's needs, (for example an outdated factory), or the building may no longer be structurally sound. These are all opportunities to salvage existing resources. The common practice in the industry is to "cherry pick" or strip out highly accessible recyclable, reusable or historic materials-prior to traditional demolition. Traditional demolition usually involves mechanical demolition, resulting in a pile of mixed debris, which is then sent to the landfill. Demolition is a fast, seemingly inexpensive society answer for structure removal. However the cost of disposal often disregards the environmental damage caused by wasteful practices. Demolition practice does not take into consideration the existing value of the materials being demolished, only the labor to remove the structure and the cost to landfill the materials.

Deconstruction

Deconstruction encompasses a thorough and comprehensive approach to whole building disassembly (versus cherry picking specialty items) allowing the majority of the materials to be salvaged for reuse (Catalli and Goode, 1997). The deconstruction process is simply the construction in reverse order. The deconstruction process has many steps and considerations that differ from traditional demolition. A brief outline of the deconstruction process considerations may be found in Table 2.4. A daily log of the steps to deconstruct a home may be found in Table 2.5.

Table 2.4 Deconstruction Considerations (CCE, 1998).

Task	Explanation
Preliminary Structure Evaluation	Locating possible structures for the deconstruction process
Permitting Process	Varies from region to region
Building Assessment	Structurally assess the building to brainstorm removal process
Building Inventory	Estimate Inventory of salvageable materials
Environmental Assessment	Investigate for Hazardous materials that must be abated
Hazardous Materials	Abate if needed
Finding Labor	Labor must be found as deconstruction jobs become available
Field Safety	Provide and prepare deconstructors with proper safety training & gear
Worker Compensation Insurance	Workers injury insurance
Scheduling	Workers, dumpsters, storage facility, material sales
Job Site Preparation	Organize and layout jobsite
Dismantling Techniques	Train workers in removing structure
Processing Techniques	Train workers in processing materials for reuse without destruction
Sorting	Organize materials
Storing	If materials are to be sold at a later date
Marketing and Resale	On site sales, reuse businesses, salvagers

Table 2.5 Daily Deconstruction Log (CCE, 1998).

Day	Deconstruction Process
Day 1	Site Cleanup and House Cleaning
Day 2	Abatement, Asbestos Tile and Mastic
Day 3	Doors, Windows, Trim, Exterior Awnings
Day 4	Oak floor, Doors, Windows, Ceiling Fans, Baseboards, Crown molding
Day 5	Plaster, Floor felt, lathe
Day 6	Lathe, sheet metal roofing, batt insulation, beadboard walls
Day 7	1 x 8 roof deck, double layer of asphalt shingles, lathe, transfer plaster debris
Day 8	2 x 4 rafters, 1 x 8 roof deck
Day 9	1 x 4 roof deck, top of chimney, transport materials to storage
Day 10	Ceiling plaster and lathe, 2 x 4 rafters
Day 11	Remove Kitchen addition to the floor deck
Day 12	Porch roof tin, asphalt shingles, mixed type wood roof deck, transport materials to storage
Day 13	No work on site
Day 14	Porch rafters, 2 x 4 studs, 1 x 6 novelty siding
Day 15	2 x 4 studs, porch rafters, 1 x 6 novelty siding, and front porch canopy
Day 16	Floor deck, 2 x 8 floor joists, foundation block and concrete
Day 17	2 x 4 studs, 2 x 4 ceiling joists
Day 18	1 x 3 floor deck, 2 x 6 floor joists, 4 x 6 floor beams, transport materials to storage
Day 19	1 x 3 floor deck, 2 x 8 floor joists, 3 x 10 and 6 x 8 floor beams
Day 20	Foundation and chimney brick, garage demolition, roof and walls
Day 21	Demo concrete, block, brick
Day 22	Demo final concrete pad, Recycle remaining metal

The deconstruction process in this example was preformed by the University of Florida's Center for Construction and Environment. A single family wood frame home was deconstructed to provide vital information and data. Although the deconstruction process is different for every structure, the outline in Table 2.5 provides the general concept of the time and labor required to deconstruct.

Nationally, deconstruction (as opposed to demolition) occurs to some extent on approximately 40% of all demolition sites over 20,000 square feet (Jefferson Recycled Woodworks, 1997). Although this figure includes buildings that are only partially deconstructed, the shift toward salvage and reuse is beginning.

Moving toward a Sustainable Environment

The construction industry's practice of landfilling construction and demolition debris results in a loss of potentially reusable building materials (CCE, 1998).

Deconstruction is a significant advance towards a sustainable environment. The immediate reuse of materials keeps existing materials in circulation and out of landfills.

In looking at the waste management hierarchy (Figure 2.5) one of the highest waste management levels is reuse (Peng et al., 1997). However, the majority of the current practices fall in the lower two levels, landfilling and burning. The most common practice on construction and demolition sites is to simply toss "waste" into the dumpster and send to a landfill. This practice often occurs because it is fast and seemingly inexpensive regardless of the potential value of the materials. Unfortunately, disposal costs or tipping fees do not accurately account for the long term environmental ramifications of throwing away potentially reusable materials. Less developed areas often burn debris on site – commonly without permits or authorization. Deconstruction assists in moving the construction industry further up the sustainability "food chain". Moving up the food chain from burning and landfilling is composting. This process is not commonly implemented on a larger scale. The next step is recycling. Most individuals are aware of curbside recycling programs that target newspaper, glass, metal and plastics. Recycling construction materials is becoming more prominent as regional struggle to reach their recycling goals and as landfills near capacity. Reuse is the most environmentally beneficial option for materials currently in circulation. By deconstructing versus demolishing it is possible to reclaim materials for reuse. At the top of the hierarchy is the most important step toward a more sustainable industry, reduce. This step is the foundation of designing for the environment. Reduction requires careful planning, rethinking current practices, and implementing sustainable alternatives.

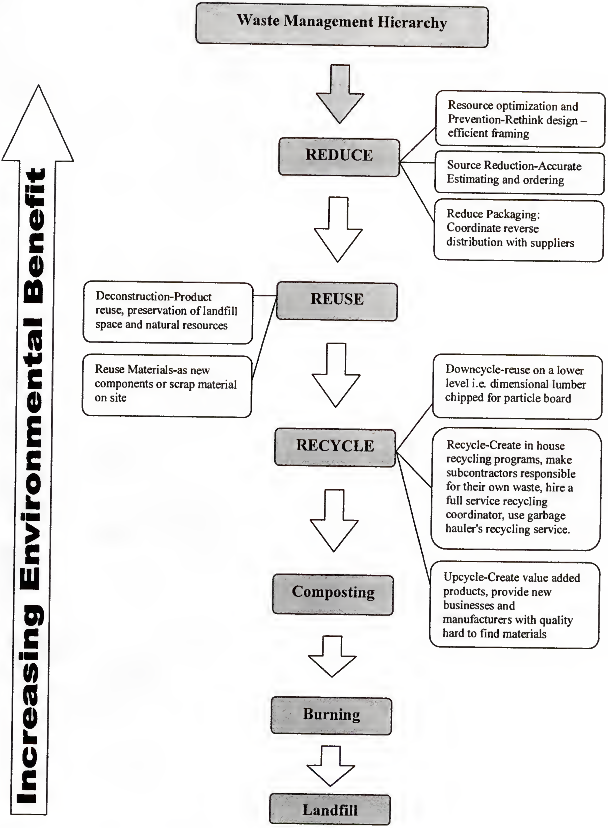

Waste Management Hierarchy
Increasing Environmental Benefit
REDUCE
Resource optimization and Prevention-Rethink design – efficient framing
Source Reduction-Accurate Estimating and ordering
Reduce Packaging: Coordinate reverse distribution with suppliers
REUSE
Deconstruction-Product reuse, preservation of landfill space and natural resources
Reuse Materials-as new components or scrap material on site
RECYCLE
Downcycle-reuse on a lower level i.e. dimensional lumber chipped for particle board
Recycle-Create in house recycling programs, make subcontractors responsible for their own waste, hire a full service recycling coordinator, use garbage hauler's recycling service.
Upcycle-Create value added products, provide new businesses and manufacturers with quality hard to find materials
Composting
Burning
Landfill

Figure 2.5 Waste Management Hierarchy (Kibert and Languell, 2000).

Sustainable Benefits of Deconstruction

Deconstruction is a process that can assist the construction industry in incorporating sustainability into current waste management practices. In regions lacking natural resources it is commonplace to reuse the supplies on hand. Structures such as old homes, barns, and buildings are used to build new or needed facilities. Regions lacking natural resources turn to locally available materials, whether they are new or borrowed materials to sustain their new construction. However the drive to reuse these materials is not limited to the lack of natural resources-it is basic common sense. Reclaimed or salvaged building materials are inherently valuable simply based on the energy and raw materials used to create them. Dismantling a building into its building components keep the materials in service as long as possible.

Environmental Benefits

There are many environmental benefits that would result from the implementation of deconstruction. Benefits such as decreasing site disturbance, conserving landfill space, saving energy by reusing materials, and decreasing air-borne lead, asbestos and nuisance dust at and around the job site (by dEsign, 1997; Catalli and Goode, 1997; Kreitner, 1996; Leroux and Seldman, 1999; NAHB, 1997). By implementing deconstruction, large amounts of usable materials can be recovered and diverted from landfills. For example, 1,000 board feet (BF) of salvaged lumber can replace up to 10,000 BF of standing timber (Center for Economic Conversion, 1997). The deconstruction effort can help counties and local communities reach recycling and landfill diversion goals.

Successful strategies for implementing salvage can greatly reduce the energy use, land consumption, groundwater degradation, deforestation and greenhouse gas production associated with wasted wood resources (Townsend and Kibert, 1997). When usable items are salvaged and diverted from landfill disposal, the need to use new raw materials and expend new energy is reduced, as are the related environmental impacts. In addition, numerous studies have documented the hazardous components of demolition waste in particular, and have pointed out the potential for resulting groundwater degradation (Hanrahan, 1994; Townsend and Kibert, 1998). Concentrated disposal of drywall, land clearing debris, and other seemingly innocuous materials may degrade groundwater quality as a result of decomposition and leaching (CCE, 1998).

Keeping materials in service longer results in reduced demolition or restoration waste, which in turn preserves landfill space. There is no additional energy spent mining new resources or manufacturing new products. Materials that are not immediately reused can be recycled, downcycled, or upcycled. Examples of these processes are the immediate reuse of large structural timbers reclaimed and used as structural members of a new building. Recycling materials would consist of turning scrap steel into new steel rebar or beams. Downcycling for example would be turning a concrete slab into road base, where upcycling would consist of salvaging lumber and creating custom cabinetry or other value-added products. Immediate reuse of materials also keeps valuable usable materials such as dimensional lumber from being downcycled into items such as oriented strand board, particleboard or mulch – which are less valuable products. Although this is better than landfilling the materials, immediate reuse provides the best conservation of materials and energy. Deconstruction supplies useful materials to building materials yards, recycling centers and remanufacturing enterprises all diverting waste from landfills.

One of the key environmental benefits of deconstruction is the preservation of landfill space. Deconstruction reduces the waste stream and extends the landfills potential service lives. Materials are separated at the source during deconstruction allowing materials that cannot be reused immediately to be recycled.

De Moines, Iowa was faced with dwindling landfill capacity. To extend the life of their construction and demolition debris landfill they began recycling an extensive list of materials. A grant from the Iowa Department of Natural Resources helped the company now called Central Construction and Demolition Recycling, Inc.-shift its business toward recycling. With five of its 23 acres dedicated to recycling, Central recycled 43% of the 87,038 tons of material it received last year.

Deconstruction, due to its hands on, non-mechanical nature, forces the proper removal and handling of hazardous materials before the remainder of the building's parts can be salvaged (by dEsign, 1997; Joslin et al., 1993; Kreitner, 1996; NAHB, 1997). During traditional demolition potentially hazardous materials often end up in the landfill simply because they were undetected. The thorough examination and exploration of structures during the deconstruction process results in the identification of hazardous materials and their proper disposal.

Debris in the mixed state requires tedious and labor intensive separation. The best way to combat this sorting barrier is to separate out the usable material prior to their reaching the landfill or recycling facility, meaning the materials should not be mixed or lumped together only to be separated again. Deconstructing allows for each material to be separated at the source, eliminating dump trucks of mixed debris. Not only does deconstruction eliminate mixed debris, it allows for the immediate reuse of materials and facilitates easier recycling because the materials can be seen as they come out of the building. It is important to note here that landfills often charge higher rates for mixed debris versus sorted debris. Deconstruction by nature creates sorted debris resulting in lower costs of disposal when material must be discarded.

Regional

Deconstruction implementation has many benefits for a region. The most general benefit is improving the region sustainability. The regions can benefit from job creation, improved environmental quality, reduction in solid waste, and economic growth (Kreitner, 1996; NAHB, 1997; Smernoff, 1997). Deconstruction is more time consuming and requires more skill than simply demolishing a structure. Although the extra time required could act as a detriment, the additional jobs that can be created benefit the community such as additional jobs and community revenue. A review of deconstruction case studies shows deconstruction requires significantly more labor than traditional demolition methods (by design, 1997, Center for Economic Conversion, 1997; Cook, 1997; Joslin et al., 1993; Keritner, 1996; NAHB, 1997; Self Reliance Inc., 1998). As a result of the labor intensity, deconstruction provides a significant amount of employment opportunities. In 1997, The Center for Economic Conversion estimated that there are ten resource recovery jobs for every one landfill job (CCE, 1998).

The basic skills needed for deconstruction can be easily learned and transferred to the construction trades. Deconstruction provides an opportunity for unskilled and low-skilled workers to contribute to a new and viable industry (CCE, 1998). These workers can receive on-the-job training in use of basic tools and techniques for carpentry, construction, and materials recovery. Training individuals can also foster community oriented enterprises such as deconstruction service companies, used building materials stores, and small manufacturing centers while protecting the community's health.

Deconstruction produces a flow of good quality, low-cost building materials into a community (Smernoff, 1997). Even when building codes prevent the use of old, ungraded boards directly in a new home, they can be used in concrete forms, walkways, and equipment sheds at the construction site (Leroux and Seldman, 1999). Deconstruction also provides opportunities for the creation of value-added products made from salvaged building materials. Deconstruction can supply useful materials to building material sales yards, recycling centers, and re-manufacturing enterprises that create additional jobs and revenue within a community.

Deconstruction provides a market for labor and sales of salvaged material (Catalli and Goode, 1997). The implementation of deconstruction results in new economic development since several businesses are needed to support a deconstruction infrastructure (Fishbein, 1998). Used Building Material Associations provide outlets for salvaged reusable materials. Jobs are created for deconstruction businesses. Business growth is experienced by demolition contractors since those who regularly demolish usually practice some form of deconstruction such as cherry picking. For example, EcoTimber of Berkeley California – a reclaimed lumber store expects revenues from its reclaimed timber sales to climb from about $100,000 last year to $500,000 this year. The company started in 1992 importing hardwood from certified well-managed forests. Because that market was small they branched into selling salvaged timber in their product lines. This year reclaimed timber will account for about 15% of the company's anticipated $4 million revenue. EcoTimber is now remilling and marketing more than 2 million board feet of timber including old-growth redwoods and Douglas fir.

The Green Institute of Minneapolis launched its DeConstruction Services in 1997 to improve the quality and quantity of inventory at the ReUse Center, its 26,000 square foot store that since 1995 has offered salvaged, reusable building materials. Now DeConstruction Services has four crews trained and insured to salvage reusable materials from buildings scheduled for demolition. About 60% of the salvaged materials sell at the deconstruction work sites or from the program's warehouse. The ReUse Center and DeConstruction Services expect more than $800,000 in sales this year.

Through deconstruction, natural resources are saved, employment and training opportunities arise, and local businesses grow from using the materials diverted from the landfill.

Deconstruction Benefits Summary

The general benefits from deconstruction are abbreviated and summarized in Table 2.6. Although only the main categories of benefits are listed here, each benefit tends to have a spider web effect branching off to intersect and affect other areas.

Table 2.6 Deconstruction Benefits.

Environmental Benefits	Regional Benefits
Decrease site disturbance	Preserve land
Conserve Landfill Space	Create jobs
Save Energy (Reuse Materials)	Spur regional growth
Decrease Airborne lead, asbestos, and dust	Provide jobs to low skilled workers
Decrease deforestation	Provide a supply of low cost building supplies
Reduce greenhouse gasses	Promote infill
Reach recycling and waste diversion goals	Sustainability
Reduce land consumption	
Reduce Groundwater degradation	

For example, although the benefit of saving energy is only listed once, energy savings occurs in many instances when materials are reused. Energy is saved from mining and processing fewer materials, therefore fewer materials to transport and market reducing energy expenditure for transportation and distribution, the embodied energy of the material is conserved during reuse, and the energy to dispose of the materials is save.

Local Motivation

The current population of Florida ranks the State as the 4th most populous state. Florida is projected to be the 3rd most populous state by the year 2025 (NPG, 1994). The growth rate of the State of Florida is approaching 2% per year while the National growth hovers around 1%. To sustain Florida's population growth – new infrastructure – schools, homes, roadways and other common amenities are needed. The growth of the State itself pushes the construction industry to provide additional infrastructure which increases C&D waste.

In the FDEP 1999 Solid Waste Management in Florida report indicates "Three types of Waste dominate Florida's MSW stream: paper, yard waste, and construction and demolition debris". These three components comprise an estimated 63% of the State's MSW collected during 1997 on a weight basis. Historic waste composition data indicates that the percentages of each type of waste component have remained fairly constant with the exceptions of C&D debris and yard waste, both of which have increased (FDEP, 1998). The total waste and C&D waste are shown in Table 2.7.

Table 2.7 Population and Waste (in tons), Florida.

Year	Population	Total Waste (MSW + C&D)	C&D Waste	% C&D Waste
1995	14,149,327	23,007,330	5,201,795	22.61%
1996	14,411,563	23,745,911	5,489,514	23.12%
1997	14,712,922	23,776,302	5,492,557	23.10%
2017*	17,586,397	34,976,554	7,927,934	22.67%
Growth Rate per year	1.9712%	1.6574%	2.7568%	

Note the above years are calendar years-this information was provided in the 1997, 1998 and 1999 FDEP Annual Report on Solid Waste Management in Florida.

*Predictions for Population calculated based on a 1.9 % rate of increase per year, Total Waste and C&D waste figures provided by the FDEP.

The accuracy of these numbers are limited because a large portion of the waste stream is handled by the private sector while the majority of the reporting is conducted by public agencies (CCE, 1998).

Florida experiences both an increase in total waste and an increase in the percentage of total waste attributed to the C&D sector. As seen in Table 2.8, the C&D percentage of total Florida waste shows a steady increase.

Table 2.8 Florida C&D Waste as a Percentage of the Total Waste Stream.

Calendar Year	C&D % of total waste
1988	6.0
1989	19.0
1990	16.6
1991	16.3
1992	20.6
1993	21.9
1994	24.2
1995	22.6
1996	23.1
1997	23.1

According to the FDEP, C&D waste was 22.61, 23.12, and 23.1 percent of the total waste stream in 1995, 1996, and 1997 respectively. The FDEP has predicted that in 2017 the C&D waste stream will remain approximately 22.67 percent of the total waste or 6,353,101 tons.

Since C&D waste is the largest single components of the total waste stream in Florida it becomes increasingly more important to target this portion of the waste stream for reduction. Especially since the majority of the waste stream is recoverable, reusable and recyclable.

In 1980, Florida had approximately 500 open dumps. During this time period, it was a common practice to either burn or use one of these open dumps in order to alleviate the solid waste. In 1994, Florida had the largest number of landfills of any state in the nation, 280 of the 1,900. Currently the State of Florida in addition to the Municipal Solid Waste landfills has 163 active construction and demolition (C&D) debris disposal facilities (FDEP, 1999). Table 2.9 below shows their locations within the State. Of these facilities, 97 are permitted as active C&D disposal facilities and 71 are permitted as land clearing facilities. Five facilities are permitted as both C&D and land clearing facilities. (FDEP, 1997)

Table 2.9 Florida Landfill Regional Locations (FDEP, 1997).

DISTRICT	Number of C&D Disposal Facilities	Number of Land Clearing Debris Disposal Facilities	TOTAL Number of Facilities per DISTRICT
Northwest	30	56	86
Northeast	11	7	18
Central	27	7	34
Southwest	17	1	18
Southeast	10	0	10
South	2	0	2
TOTALS	97	71	168
Total Facilities	163	Five are both C&D and LC Facilities	

Prior to 1996 Florida experienced a steady growth in the number of C&D facilities. Since 1996 there has been a significant drop in the total number of permitted C&D disposal facilities partially due to new C&D regulations. The decreasing number of C&D landfills is not a Florida specific phenomenon, but a result of land scarcity and increasing state and national regulations. With the number of permitted landfills decreasing and the growth continuing priority should be placed on properly managing the solid waste generated.

Florida's rapid population growth unfortunately is not uniform throughout the State. Popular coastal regions of the State are becoming more densely populated and land is being sold at a premium.

To further examine Florida's potential for deconstruction implementation, the location of the States landfills were analyzed. The State was broken into 6 regions – the same divisions used by the Florida Department of Environmental Protection (FDEP). Table 2.8 shows that the majority of Florida's landfills are located in the northwest section of the State. The northwest section is closely followed by the central region with respect to C&D debris facilities. However, if the land clearing debris facilities are included, the northwest region contains approximately 2 ½ times the landfills contained in any other region of the State. The concentration of the landfills in the northwest and central portions of the State are primarily due to the mining industry. In addition to the mining industry, these sections of the State have a less dense population than coastal and southern areas of Florida. The mining industry left many open pits which the industry calls abandoned quarries. These quarries lend themselves perfectly to becoming landfills.

Tipping fees are also a important factor in the waste disposal industry. Although the average tipping fees throughout the State are fairly constant, some variation may be noted. Average tipping fees based on Florida regions are presented in Table 2.10. In general the highest tipping fees are in the southern portion of the State-which tends to be the most populated area. Tipping fees are somewhat lower in the north and central regions of the State where the cost of purchasing land for landfills tends to be less than that in more metropolitan areas to the south.

Table 2.10 Florida Regional Average C&D Tipping Fees (shown in $/ton) for C&D Disposal.

Region	1997	1998	1999
South	$36.91	$36.91	$31.68
Southeast	$31.28	$31.14	$30.35
Southwest	$33.03	$31.51	$31.51
Central	$28.05	$26.62	$29.36
Northeast	$32.38	$31.36	$34.50
Northwest	$28.38	$33.06	$31.28
Average	$31.67	$31.76	$31.44

The highest tipping fee was found in Monroe County in the South region of the State with tipping fees of $92.00 per ton. The lowest tipping fee was found in Glades County where the fees are $5.00 per ton (FDEP, 1998). Figure 2.6 identifies these regions and shows the regional average tipping fees.

Although there are regions in the State where the tipping fees are higher than the nation's average (approximately $44.50), for the most part the tipping fees throughout the State are low.

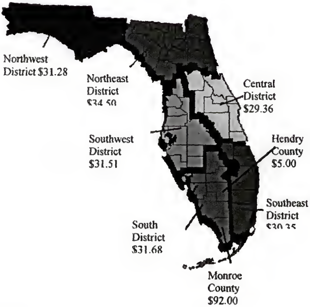

Northwest District $31.28
Northeast District $34.50
Central District $29.36
Southwest District $31.51
Hendry County $5.00
Southeast District $30.35
South District $31.68
Monroe County $92.00

Figure 2.6 Florida State Map Containing High, Low and Average Tipping Fees.

Summary

Sustainability is an all inclusive term that defines a goal that can be achieved through many smaller efforts. One small component of moving toward sustainability is developing in a sustainable manner and adopting sustainable practice such as deconstruction instead of traditional C&D waste disposal. The national C&D waste stream in the U.S. is 136 million tons of waste per year. This accounts for over one third of all waste generated annually. This literature review showed that other countries experience similar quantities of C&D waste. Deconstruction is a process that can remove salvaged materials from the demolition and renovation portions of the C&D waste stream. The deconstruction process also has significant regional and environmental benefits. Implementing deconstruction as a waste reduction strategy can assist the construction industry in moving further up the waste management hierarchy.

CHAPTER 3
DECONSTRUCTION CASE STUDY ANALYSIS

Introduction

There are many possible processes and techniques that could be investigated to reduce the waste stream. At the beginning of this research project it was discovered that the process of deconstruction was beginning to emerge only sporadically throughout the U.S. as indicated in the few case studies involving reclaiming materials as part of a primary focus on diverting waste from landfills. This chapter specifically focuses on the investigation of deconstruction for its potential to reduce the landfilled C&D waste stream. The primary goal is to determine:

1. The types of salvaged materials generated from single family wood frame residential structures,
2. The quantity of each materials salvaged,
3. The achievable diversion rate from salvaging for reuse and recycling,
4. Assembling a preliminary list of factors influencing the success of deconstruction
5. And to isolate the influence factors specific to implementing a regional waste reduction strategy from the structure and contractor specific variables.

Two means of data collection were used to attain the needed information. The first was using existing case study data, and second, the systematic and planned data collection from the deconstruction of six single-family residential structures in the test area. An extensive search of case studies from international and domestic regions was conducted and revealed that only a handful of actual documented deconstructions had been accomplished and published. Data such as the cost to deconstruct, labor requirements, time requirements, the quality and quantity of materials that could be salvaged, and their resale potential was colleted from these case studies. The preliminary assessment of the deconstruction process revealed a high potential for waste diversion.

The second data collection process consisted of the deconstruction of six structures. Each of the six test projects specifically addressed the complete removal of a structure, deconstruction methods, materials issues, labor and cost factors, profitability, and waste diversion rates. These data were used to validate the case study data and provide additional data to further define material component types, quantities, diversion rates, and identification of the primary factors influencing the success of the deconstruction process.

In this chapter the research scope is refined, the residential portion of the national waste stream is isolated, domestic, international and test area deconstructions are reviewed and presented for the composition of salvaged components, and the potential diversion rates are determined.

Refining the Scope of Work

While investigating the deconstruction process, case studies revealed a key issue had to be addressed. The waste stream generated from different construction types produces a distinctly different waste stream. For example, the deconstruction of a commercial structure will yield a different waste stream than the deconstruction of a residential structure. As shown in Figures 3.1, 3.2, 3.3, and 3.4 the percent composition of the waste stream varies significantly depending on the structure type.

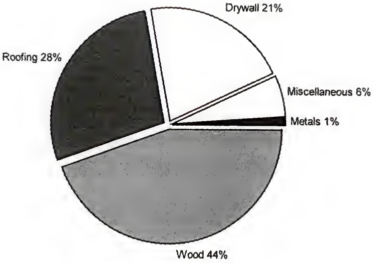


Figure 3.1 Sample Composition of Residential Renovation Debris (Average of two sites, METRO Portland, Oregon, (Franklin Associates, 1998)).

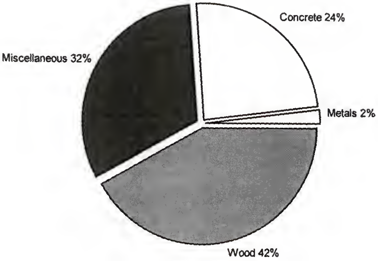


Figure 3.2 Sample Composition of Residential Demolition Debris (Average of three sites, METRO Portland, Oregon, (Franklin Associates, 1998)).

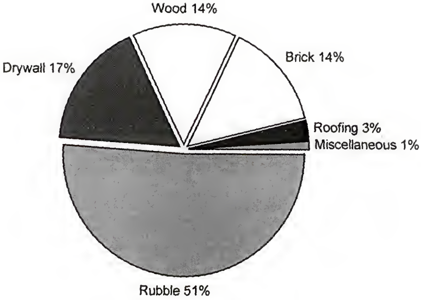


Figure 3.3 Sample Composition of Multi-family Demolition Debris (NAHB Research Center Inc. Franklin Associates, 1998).

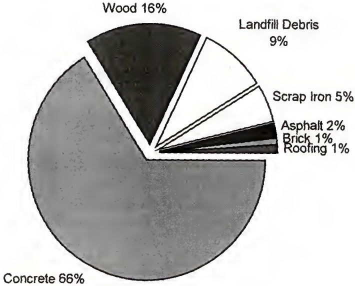


Figure 3.4 Sample Composition of Non Residential Demolition Debris (19 projects in the Pacific Northwest, R.W. Rhine, Inc., Tacoma, Washington (Franklin Associates, 1998)).

It was necessary to refine the scope of work for several reasons.

1. Residential and commercial deconstructions produce different waste streams
2. Different residential construction types produce different waste streams
3. Structures available for deconstruction in the test area were single family wood frame residential structures.

Isolating a structure type allowed for a more accurate description the resulting waste stream. Due to the variability of waste types and quantities generated based on structure type and the structures available for deconstruction, the scope of this work was narrowed to single family wood frame residential structures.

Accurate knowledge of the waste stream will allow for the proper assessment of the outlets needed to support the deconstruction process and for calculation of the diversion rate. If the waste is to be diverted, there must be an outlet and markets to absorb the materials. The end diversion rate depends on the materials reclaimed, outlets available and the market for each material.

As the focus of this deconstruction research has been narrowed to the residential sector, it was first necessary to isolate the residential portion of the national C&D waste stream. In addition, the case study review will specifically address residential deconstructions, the materials generated and the diversion potential. Residential, commercial, and industrial case studies, in addition to the test area deconstructions, will be used to develop a preliminary list of factors and variables influencing the success of the deconstruction process.

Isolating the National Residential Waste Stream

The total annual C&D waste stream in the nation is 136 million tons. The component breakdown of this waste stream is shown in, Figure 3.5.

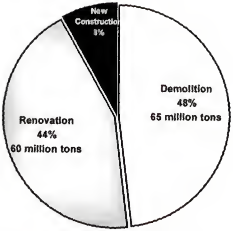


Figure 3.5 C&D Demolition, Renovation, and New Construction Waste Sectors.

The demolition and renovation sectors were broken into residential and non residential components. The *Characterization of Building Related Construction and Demolition debris in the United States* report provides Table 3.1.

Table 3.1 Summary of Estimated Building –Related C&D Debris Generation , 1996 (Roadway, Bridge, and Land Clearing Debris not included (Franklin Associates, 1998)).

Source	Residential		Non Residential		Totals	
	Thousand tons	**Percent**	**Thousand tons**	**Percent**	**Thousand tons**	**Percent**
Construction	6,560	11	4,270	6	10,830	8
Renovation	31,900	55	28,000	36	59,900	44
Demolition	19,700	34	45,100	58	64,800	48
Totals	58,160	100	77,370	100	135,530	100
Percent	43		57		100	

Demolition Waste Stream

The total demolition waste stream is 64,800,000 tons. The residential portion of this waste stream is 19,700,000 tons while the non-residential portion is 45,100,000 tons. The residential portion of the demolition waste stream is 30% as shown in Figure 3.6

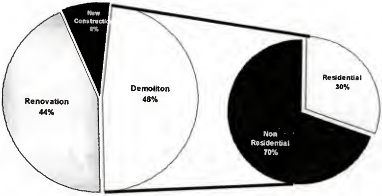


Figure 3.6 Residential and Non residential Components of Demolition Waste Sector.

Reviewing the renovation portion, 59,900,000 tons of the waste stream, reveals 31,900,000 tons of residential renovation waste and 28,0000,000 tons of non- residential waste. The residential portion of the renovation waste stream is 53% as shown in Figure 3.7.

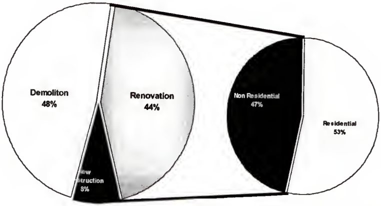


Figure 3.7 Residential and Non residential Components of Renovation Waste Sector.

In summary, the total residential portion of the C&D waste stream resulting from demolition and renovation activities is 51,600,000 or 38% of the total C%D waste stream. Figure 3.8 shows the residential and non-residential waste stream breakdown.

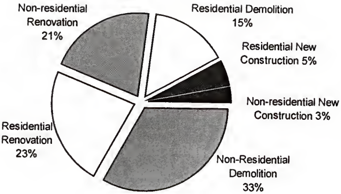


Figure 3.8 Residential versus Non-Residential C&D Debris.

Deconstruction General

The deconstruction process has been occurring for centuries. It is common practice in regions lacking raw materials and natural resources to reuse materials at hand. Recently the deconstruction process has been investigated for its potential as a waste reduction strategy. Deconstruction for research purposes has been conducted to a limited degree both internationally and domestically. The location and the structure of each deconstruction case study have been very different. The deconstructions were often subsidized with research grant funds to allow for data collection. There were two main focuses of these case study deconstructions, first, to determine the cost effectiveness of the deconstruction process as compared to demolition, and second, to determine the quantity and quality of materials generated from the removal of the structures. The data collection methods and actual data collected during each of the case studies varied depending on the primary purpose of the deconstruction process. Information from the case studies often included:

- Composition of salvaged materials in weight percent

- Composition of salvaged materials in volume percent
- Waste generation rate in pounds per foot
- Percent of material diverted from the waste stream
- Cost to deconstruct (for example time to deconstruct and personnel required)

The case studies also included regionally specific information such as labor rates and climate information. Additional information included lessons learned such as deconstruction techniques and material marketing suggestions.

Domestic Residential Deconstruction Case Studies

The case study deconstructions conducted for the purpose of research provide information that is needed to determine the potential impact deconstruction could have on a regions' C&D waste stream. The most important information needed from the case studies is related to the components and quantities of the waste stream generated from these deconstructions and the achievable waste diversion rate.

by dEsign consultants (Ottawa, Ontario-1996)

This deconstruction project was conducted in Canada where the C&D waste stream is approximately 25 – 33 % of the total Canadian waste stream (by dEsign, 1997). This deconstruction project was conducted in cooperation with Canada Mortgage and Housing Corporation (CMHC), Tamarack Development Corporation, BFI Waste Systems, Goode-X Equipment Ltd., Eco-Mat Inc., and the Regional Municipality of Ottawa Carleton (RMOC). Eight deconstructors began this project by "test deconstructing" partially disassembling four structures. The "test deconstructions" were essentially to overcome the learning curve associated with beginning any new process. The case study structure for deconstruction data collection consisted of a 4 story house (including a basement) which encompassed 6,627 square feet (SF), a 2 story barn with

2,769 SF and a 1 story garage with 290 SF. The primary goal was to deconstruct the 9,686 total SF of structures reusing or recycling as close to 100% of the building materials as possible. The waste resulting from this deconstruction study is presented in Table 3.2.

Table 3.2 by dEsign Recovered Materials.

Material	**Weight Percent**	**Volume Percent**
Concrete	77.00%	34.90%
Wood	11.00%	26.30%
Finishes/Furnishings	4.00%	5.48%
Roof Membrane	2.80%	0.70%
Metals	2.00%	0.20%
Insulation	1.43%	28.80%
Doors & Windows	0.83%	1.00%
Other Materials	0.94%	2.62%

The weight percent and volume percent pie charts are shown in Figure 3.9 and 3.10 respectively.

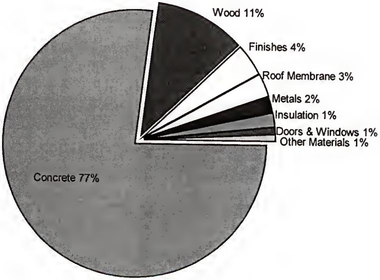


Figure 3.9 by dEsign Case Study Recovered Materials Composition (Weight Percent).

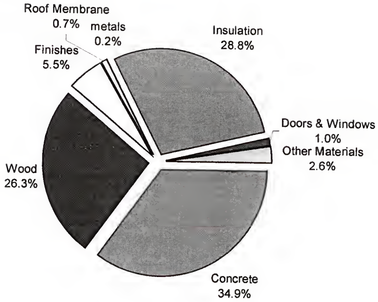


Figure 3.10 by dEsign Case Study Recovered Materials Composition (Volume Percent).

As seen in these figures, the top 3 components based on weight percent are concrete, wood, and finishes/furnishings. The top three components based on volume percent are concrete, wood, and insulation.

Both the weight percent and volume percentage of salvaged materials provide useful information for analyzing the waste stream. As the capacity of a landfill is measured in volume, the volume percentage can assist in determining the physical space saved in landfills from diversion efforts. Unfortunately, there is no easy method of eliminating the voids, or air spaces, that commonly result while filling a dumpster. This can result in limited accuracy of volume calculations. Some landfill charges are based on the "load" or dump truck full of materials while other landfills charge by the tons of debris (Townsend, 1998). In this case, the weight percentage of the materials is beneficial for comparison. Understanding the weight components that are responsible for the majority of the tipping fees resulting from structure removal can assist the contractor in targeting these specific materials for reduction. Unfortunately, the weight percentage does not necessarily paint an accurate representation of the quantity of different materials removed from a job site due to the inherent properties of some materials. For example the weight of concrete often makes it the largest weight percent component even though it may not be the largest volume component.

The "by dEsign" project employed 6 individual workers for 4 weeks versus traditional demolition that would have employed 2 workers and 4 equipment operators for 4 days. The total waste that would have been generated from the deconstruction of these structures was estimated at 33 waste bins – each containing 30 cubic yards (CY) of unconsolidated debris. As a result of the deconstruction effort, only 8 bins were sent to the landfill resulting in a diversion rate of approximately 75.8% (by dEsign, 1997).

Whole House Recycling Project (Portland, Oregon-1992)

Over several weeks, this non-mechanized demolition occurred with the primary intent to recover as much reusable and recyclable material as possible. This project was initiated to address the loss of resources associated with landfilling potentially reusable material. The residential structure deconstructed for this project was 1280 square feet (Joslin et al., 1993). The component breakdown of materials removed from the structure is listed in Table 3.3.

Table 3.3 Whole House Recovered Materials.

Material	Weight Percent	Volume Percent
Misc. Debris	22.4%	25.0%
Wood Scrap	20.5%	20.0%
Concrete	32.8%	25.0%
Lumber	19.1%	25.0%
Brick	2.9%	
Scrap Metal	12.0%	
Doors & Frames	0.2%	
Exterior Doors	0.1%	
Misc. Hardware	0.3%	

Figure 3.11 and 3.12 show the weight percent and volume percentage respectively of the materials recovered from the whole house deconstruction project.

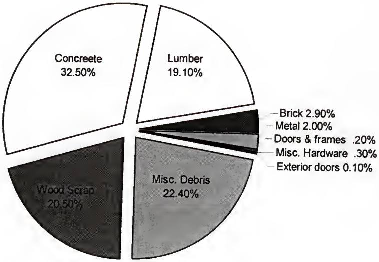


Figure 3.11 Whole House Recovered Materials Composition (Weight percent).

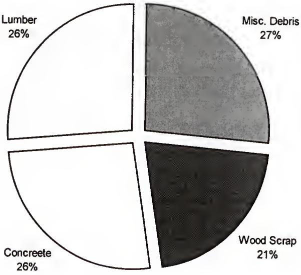


Figure 3.12 Whole House Recovered Materials Composition (Volume percent).

The top components based on weight percent were concrete, wood scrap, lumber and metal. The miscellaneous debris category was disregarded because it is not composed of any one specific building component. This research study grouped the volume percent component breakdown into 4 categories; wood scrap, concrete, lumber, and miscellaneous debris. The volume percentages were grouped because accurate quantities are often difficult to attain due to the percentage of voids formed in the dumpsters. The varying shapes and sizes of materials do not allow for precise measurements.

Of the total material removed, 77.6 weight percent of the material was recovered and 22.4 weight percent of the material was landfilled (Joslin et al., 1993). The materials recovered were either recycled or reused. In this case study, 70.9% of the recovered material was recycled and 29.1% of the recovered material was reused. Figure 3.13 shows the fate of each materials category. The lumber, brick, doors and frames, miscellaneous hardware, and exterior doors were reused. The concrete, wood scrap, and metal was recycled while the miscellaneous debris was landfilled. The light gray and black shaded regions in this figure represent materials diverted from landfills. It is easy to see that less than one quarter of the materials were landfilled.

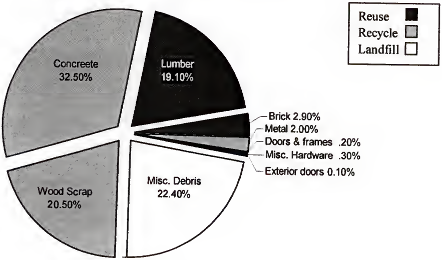


Figure 3.13 Reused, Recycled and Landfilled Materials (shown using weight percent).

The deconstruction of this 1280 SF structure generated 92,175 pounds of materials. This corresponds to a waste generation rate of 72 pounds per square foot (#/SF).

Riverdale (Baltimore County, Maryland)

The Riverdale case study was conducted with the primary intent of addressing the cost competitiveness of deconstruction versus demolition. Table 3.4 shows the component and percentage breakdown of the salvaged materials resulting from the 2,000 SF 4-unit residential structure deconstruction (NAHB, 1997).

Table 3.4 Riverdale Materials Composition.

Material	Weight Percent	Volume Percent
Framing Lumber/Sheathing	6.3%	17.9%
Brick	14.1%	4.4%
Hardwood Floors	0.9%	2.6%
Stairs	0.3%	1.5%
Windows	0.2%	0.7%
Tubs/Toilets/Sinks	0.6%	1.1%
Doors	0.3%	1.1%
Shelves	0.1%	0.2%
Kitchen Cabinet	0.2%	0.4%
Rubble	48.4%	32.2%
Metal	1.8%	4.8%
Asphalt Shingles	2.8%	3.7%
Plaster	17.0%	17.6%
Painted Wood	3.3%	9.5%
Rubble	3.9%	2.6%

Figures 3.14 and 3.15 show the volume and weight percentages respectively of the materials deconstructed. The top three categories based on weight percent are rubble (concrete and brick), plaster, and brick. The top three categories based on volume percent are framing lumber/sheathing, rubble (concrete and brick), and plaster.

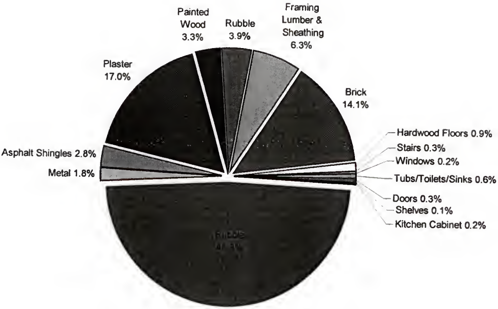


Figure 3.14 Riverdale Recovered Material Composition (Weight Percent).

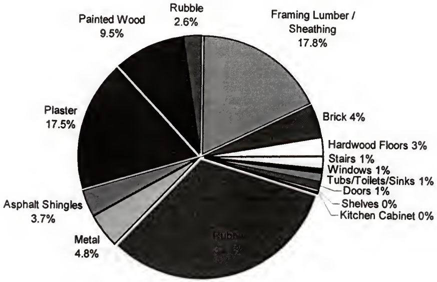


Figure 3.15 Riverdale Recovered Material Composition (Volume Percent).

Not all of the materials that came out of the Riverdale study were diverted. The diversion rate, by weight percent, was approximately 75.9%. Meaning only 24.1 % of the materials were landfilled. Figure 3.16 shows the materials that were reused, recycled and landfilled.

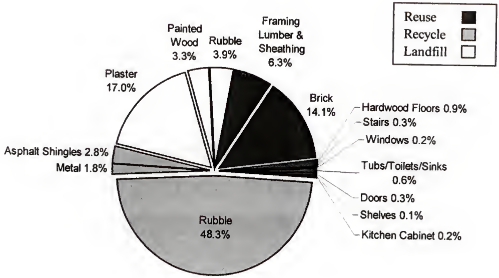


Figure 3.16 Riverdale Reused, Recycled and Landfilled Materials (shown using weight percent).

The light gray and black shaded areas represent the materials that were diverted from the landfill. Again, it may be seen that less than one quarter of the materials by weight were landfilled.

CIB International Residential Case Study Data

Due to the variability of data recording processes, the international information is limited on residential deconstructions. The first case study is from Australia. The case study only provided the recovery rate of each material. The case study does not provide information regarding the percentage of each material as a component of the whole house. The recovery rate of each material type salvaged is listed in Table 3.5. It is important to note the case study did not indicate if the following data was weight or volume percent.

Table 3.5 Australia Case Study Recovery Rate for each residential component (Crowther, 2000).

Materials	% Recovered
Brick	77%
Timber	79%
Structural Steel	78%
Doors	71%
Windows	73%
Iron Roofing	88%
Flooring	78%
Roof Tiles	50%
Plumbing	73%

A second international case study from Germany provides the composition of a residential demolition. The components and their percentages are found in Table 3.6.

Table 3.6 Components and percentages of German residential demolition (Schultman and Rentz, 2000).

Material	Percentage
Brick & Stone	50.32%
Concrete	25.5%
Wood	13.4%
Gypsum & Mortar	9.2%
Steel	0.9%
Metal	0.2%
Plastic	0.6%

Test Area Deconstruction Case Studies

The Center for Construction and Environment received funding through the Florida Department of Environmental Protection Innovative Recycling Projects grant program. This grant served to fund the deconstruction of homes for the purpose of examining the cost effectiveness of deconstruction and salvage when compared to traditional demolition. Data on six homes deconstructed in the Gainesville Florida area is provided below. The homes deconstructed were all wood frame single-family residential structures. These homes are representative of residential demolitions throughout the

United States (CCE, 2000). Approximately 94% of all residential buildings built each year in the US are light wood framed construction of a type similar to those in this study. (CCE, 2000).

2930 NW 6th (Gainesville 2930)

This one story structure was originally constructed in 1915. The total square footage of the structure, the structures three additions, and a CMU (concrete masonry unit) garage was 2,014 SF. The material composition data resulting from the deconstruction of this house is shown in Table 3.7.

Table 3.7 Gainesville 2930 Deconstruction Material Composition Data.

Material	**Weight (tons)**	**Weight Percent**	**Volume (cubic yards)**	**Volume Percent**
Brick	1.56	1.64%	5.69	3.22%
Framing Lumber	26.35	27.62%	24.53	13.89%
Windows	0.14	0.15%	3.33	1.89%
Concrete and Brick Rubble	43.84	45.95%	70.00	39.65%
Metal	1.40	1.47%	10.00	5.66%
Plaster	3.57	3.74%	8.00	4.53%
Painted wood & Mixed Debris	14.66	15.36%	45.00	25.49%
Mixed Roof Debris	3.89	4.08%	10.00	5.66%
Total	22.12	100.00	63.00	100.00

Figures 3.17 and 3.18 show the volume and weight percentages respectively of the materials resulting from the deconstruction. The top three categories based on weight percent are concrete and brick rubble, framing lumber, and painted wood and mixed wood debris. The top three categories based on volume percent are concrete and brick rubble, painted wood and mixed wood debris, and framing lumber.

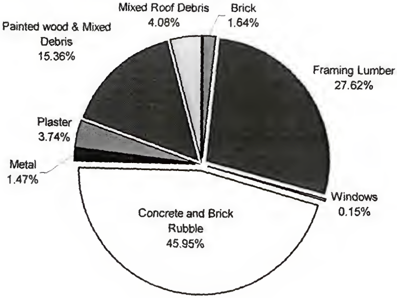


Figure 3.17 Gainesville 2930 Deconstructed Building Components (weight percent).

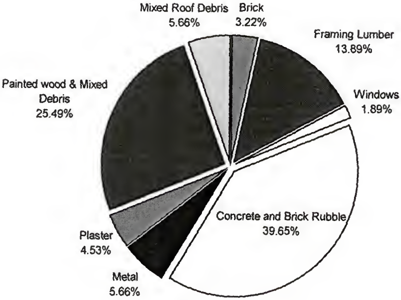


Figure 3.18 Gainesville 2930 Deconstructed Building Components (volume percent).

The diversion rate was approximately 76.82% by weight and 64.32% by volume. Figure 3.19 shows the materials that were reused, recycled and landfilled. The deconstruction of this structure resulted in a 76.8% diversion rate.

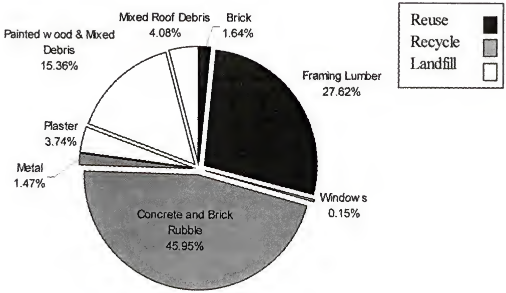


Figure 3.19 Gainesville 2930 Reused, Recycled and Landfilled Materials (shown using weight percent).

711 NW 7th

This two-story structure was originally constructed in 1945. The total square footage of this structure and one addition was 1,436 SF. It should be noted that this structure was in poor condition and was not a favorable structure for deconstruction. The removal of this structure resulted in a disproportionately high percentage of debris versus salvageable materials due to the structures condition. The material composition data resulting from the deconstruction of this house is shown in Table 3.8.

Table 3.8 Gainesville 711 Deconstruction Material Composition Data.

Material	**Weight (tons)**	**Weight Percent**	**Volume (cubic yards)**	**Volume Percent**
Brick	4.45	15.35%	2.75	1.91%
Clawfoot tub and sink	0.17	0.59%	2.37	1.65%
Framing Lumber	0.24	0.83%	0.58	0.40%
Windows	0.13	0.45%	0.15	0.10%
Concrete and Brick Rubble	1.67	5.76%	3.00	2.09%
Metal	1.50	5.17%	15.00	10.43%
Plaster	2.46	8.49%	3.65	2.54%
Painted wood & Mixed Debris	17.92	61.81%	115.59	80.35%
Mixed Roof Debris	0.45	1.55%	0.76	0.53%
Total	28.99	100.00	143.85	100.00

Figures 3.20 and 3.21 show the volume and weight percentages respectively of the materials deconstructed. The top three categories based on weight percent are painted wood and mixed wood debris, brick, and plaster. The top three categories based on volume percent are painted wood and mixed wood debris, metal, and plaster.

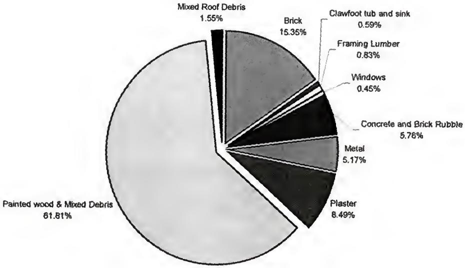


Figure 3.20 Gainesville 711 Deconstructed Building Components (weight percent).

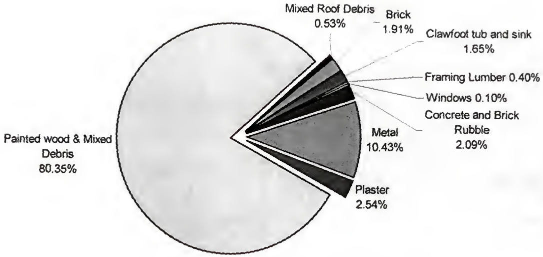


Figure 3.21 Gainesville 711 Deconstructed Building Components (volume percent).

The diversion rate was approximately 39.17% by weight and 16.58% by volume. Figure 3.22 shows the materials that were reused, recycled and landfilled.

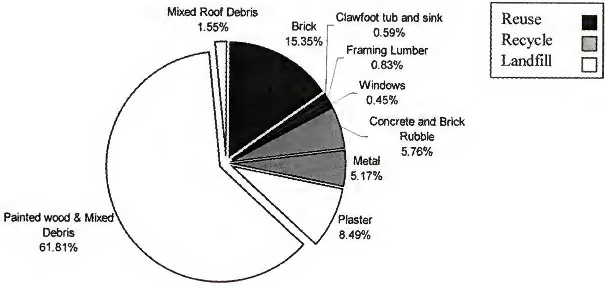


Figure 3.22 Gainesville 711 Reused, Recycled and Landfilled Materials (shown using weight percent).

The deconstruction of this structure resulted in a 28.2% diversion rate. The low diversion rate was a result of the poor condition of the structure.

14 NW 4th (Gainesville 14)

This two-story structure was originally constructed in 1900. The total square footage of this structure and one addition was 2,059 SF. The material composition data resulting from the deconstruction of this house is shown in Table 3.9.

Table 3.9 Gainesville 14 Deconstruction Material Composition Data.

Material	Weight (tons)	Weight Percent	Volume (cubic yards)	Volume Percent
Brick	4.58	11.38%	2.83	1.23%
Doors	0.09	0.22%	1.33	0.58%
Insulation	1.08	2.68%	26.75	11.60%
Roofing Sheet Metal	1.53	3.80%	2.67	1.16%
Miscellaneous Material	0.63	1.57%	27.26	11.82%
Framing Lumber	9.94	24.71%	27.08	11.75%
Stairs	0.22	0.55%	0.56	0.24%
Windows	0.23	0.57%	1.67	0.72%
Concrete and Brick Rubble	2.94	7.31%	3.32	1.44%
Metal	3.00	7.46%	30.00	13.01%
ACM Plaster/Drywall	3.17	7.88%	7.00	3.04%
Painted wood & Mixed Debris	12.46	30.97%	100.00	43.38%
Mixed Roof Debris	0.37	0.92%	0.06	0.03%
Total	40.23	100.00	230.53	100.00

Figures 3.23 and 3.24 show the volume and weight percentages respectively of the materials deconstructed. The top three categories based on weight percent are framing lumber, Painted wood and mixed wood debris, and brick. The top three categories based on volume percent are painted wood and mixed wood debris, metal, and framing lumber (excluding the miscellaneous debris category).

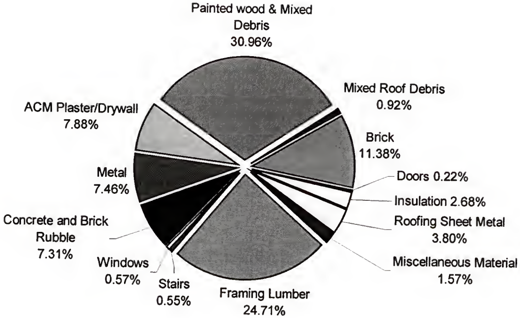


Figure 3.23 Gainesville 14 Deconstructed Building Components (weight percent).

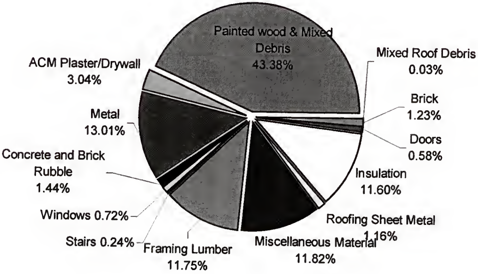


Figure 3.24 Gainesville 14 Deconstructed Building Components (volume percent).

The diversion rate was approximately 52.92% by weight and 52.12% by volume. Figure 3.25 shows the materials that were reused, recycled and landfilled.

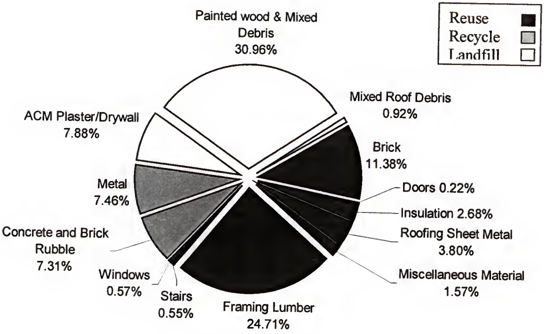


Figure 3.25 Gainesville 14 Reused, Recycled and Landfilled Materials (shown using weight percent).

Due to personnel and funding constraints, less extensive data were collected on the remaining three structures.

Gainesville 2812

This one story structure was originally constructed in 1900. The total square footage of this structure and two additions was 1,238 SF. The total tonnage of materials produced by this structure was 24.76 tons or 39.39 lbs/sf (CCE, 2000). Due to implementing deconstruction techniques, only 7.90 tons of material was landfilled. This corresponds to a diversion rate of 68.09%.

Gainesville 901

This one story structure was originally constructed in the 1920"s. The total square footage of this structure and three additions was 992 SF. The total tonnage of material produced by this structure was 22.32 tons or 45.00 lbs/sf (CCE, 2000). Implementing deconstruction resulted in 5.30 tons of landfilled waste. The resulting diversion rate is 76.25%.

Gainesville 3650

This one story structure was originally constructed in 1950. The total square footage of this structure and one addition was 1,118 SF. The total tonnage of materials produced by this structure was 32.42 tons or 58.00 lbs/sf (CCE, 2000). Deconstruction techniques resulted in only 12.00 tons of landfilled materials. The resulting diversion rate is 62.98%.

Summary of Residential Case Studies

Due to the variety of case study structures, locations, individuals collecting data, and the type of data collected unifying all of the case study data was not completely possible. Most of the diversion rates were reported or could be calculated from data collected and ranged from 28.20% to 77.60%. The average diversion rate was approximately 67%. The pounds of waste generated per square foot ranged from 29.39 to 127.2. The average waste generation is 66 lbs/sf. A summary of the case study information is found in Table 3.10.

Table 3.10 Residential Case Study Summary.

Case Study	Pounds of waste generated /Square Foot of structure	diversion (wt %)	Highest Percent Materials	
			Weight Percent	Volume Percent
by design	NA	75.80%	Concrete, wood, finishes	Concrete, wood, insulation
Whole house	72 without concrete 95 with concrete	77.60%	Concrete, wood and lumber, metal	Wood and lumber, concrete, miscellaneous
Australia	92.9	NA	NA	NA
Germany	NA	NA	brick & stone, concrete, wood	NA
Riverdale	127.2	75.90%	Rubble, plaster, brick	Framing lumber and sheathing, rubble, plaster
Gainesville 2930	94.75	76.80%	Concrete and Brick Rubble, Framing lumber, painted wood & mixed debris	Concrete and Brick Rubble, Framing lumber, painted wood & mixed debris
Gainesville 711	40.38	28.20%	painted wood & mixed debris, brick, plaster	painted wood & mixed debris, metal, plaster
Gainesville 14	39.08	52.90%	painted wood & mixed debris, framing lumber, brick	painted wood & mixed debris, metal, framing lumber
Gainesville 2812*	29.39	68.09%	NA	NA
Gainesville 901*	45	76.25%	NA	NA
Gainesville 3650*	58	62.98%	NA	NA
*(CCE, 2000)				

Commercial Case Study Waste Quantities

Although not specifically addressed by this research or the assessment tool, it is important to look at the recovery rates of commercial deconstruction projects. The commercial deconstructions tend to produce a larger concrete based waste stream which is more conducive to recycling than reuse. These case studies were reviewed to assist in the development of the influence factors governing the deconstruction process, which were used in developing the assessment tool. It is important to point out that commercial deconstructions also achieve high diversion rates through recycling.

The following recovery rates listed in Table 3.11 are from non-residential case studies. These rates show the potential that implementing deconstruction can have on reducing the waste stream. The recovery rates range from 50-95 percent.

Table 3.11 Non Residential Deconstruction Project Recovery Rates (Leroux and Seldman, 1999).

Location	**Case Study**	**Reuse/Recycling Rate**
San Francisco, CA	Presidio	87%
Fort McCoy, WI	USArmy barracks	85%
San Diego, CA	US Navy Motor Pool building	84%
Marina, CA	Fort Ord	80-90%
Twin Cities, MN	Army ammunition plant	60-80%
Port of Oakland, CA	Warehouse	70%
Minneapolis, MN	Residential building	50-75%
British Colombia, Canada	Prison complex	95%

Although at first glance these numbers seem high this is the total amount of waste diverted from the landfill. The numbers do not necessarily represent the percentage of materials that were deconstructed and specifically reused. The percentages represent the total diversion rate through both reuse and recycling. These numbers include recycled materials such as a concrete slab material that is crushed and used as road base or the glass from windowpanes sent to a recycling facility.

Identifying the Factors that Influence Deconstruction

The next phase of this research required analysis of the deconstruction case studies to identify all factors that influence the deconstruction process. This analysis included both residential and commercial case studies, deconstruction research reports, and the test area deconstruction from which a list of influence factors and variables that affect the deconstruction process were developed.

For the purpose of this research the term influence factor will be used as a general category of factors that influence the implementation of deconstruction, for example, regional growth. Regional Growth considerations are important in the deconstruction process, but regional growth is not in itself a specific variable, but a general category under which variables can be found. Regional growth can be measured in many ways, such as population, population growth rate, or the number of building permits issued. Each of these measurable terms are referred to as variables.

The influence factors and variables identified through the analysis of research reports and case studies were broken into 3 categories: 1. Independent variables, 2. Structure dependent variables, and 3. Location dependent variables. For this research, independent variables are those that represent the benefits of deconstruction; if implemented, these benefits often result even though they may be difficult to quantify. The independent variables are listed in Table 3.12.

Table 3.12 Independent Deconstruction Variables.

Variable	**Characteristic**
Environmental Benefit	Qualitative, Quantitative
Natural Resource Conservation	Qualitative, Quantitative
Preservation of Landfill space	Quantitative
Conservation of materials embodied energy	Qualitative, Quantitative
Reduce Waste	Quantitative
Economic Benefit	Quantitative
Job creation	Quantitative
Business creation	Quantitative
Low cost of new materials	Quantitative

Regardless of the location at which the deconstruction occurs or the type of structure targeted for deconstruction, the deconstruction process can result in the benefits of job creation, waste diversion, and a reduction in demand for virgin materials.

There are many factors that influence or are influenced by, the specific structure and location of the deconstruction project. This will result in. first, structure dependent variables, and second, location dependent variables. Structure dependent deconstruction variables depend specifically on the type of structure that has been slated for deconstruction. These variables are inherent to the building, the construction techniques used, the structural itself and the finishing materials. The structure dependent deconstruction variables are listed in Table 3.13.

Table 3.13 Structure Dependent Deconstruction Variables (CCE, 1998).

Variable	Characteristic
Planning for the deconstruction process	Quantitative
Training in deconstruction techniques	Quantitative
Project Length /Deconstruction Time	Quantitative
Material Sorting/Inventory/Storage/Grading/Resale	Quantitative
Safety/Hazardous Materials	Quantitative
Deconstruction Labor Required	Quantitative
Quantity of reusable materials	Quantitative
Quality of reusable materials	Qualitative
Quantity of recyclable materials	Quantitative
Quality of recyclable materials	Qualitative

Many factors that strongly influence the successful implementation of the deconstruction process are regionally dependent, meaning that the same deconstruction process may prove successful or unsuccessful depending on the location or region of the project. Success, for example may be defined by achieving the desired diversion rate. Table 3.14 identifies variables that are location or regionally dependent.

All of these variables influence the deconstruction process; however, not all of these variables influence the implementation of deconstruction as a regional waste reduction strategy.

Table 3.14 Location Dependent Variables.

Variable		Characteristic
Growth	Growth rate	Quantitative
Population Growth		Quantitative
Building Permits/ Permitting		Quantitative
Economy	Unemployment Rate	Quantitative
Per Capita Personal Income		Quantitative
Deconstructable Building Stock	Quantities	Quantitative
Age		Quantitative
Types		Quantitative
Number of Demolitions		Quantitative
Number of Renovations		Quantitative
Tipping Fees		Quantitative
Labor Rates		Quantitative
Demolition Policy		Quantitative
Waste Management Regulations		Quantitative
Permitting process		Quantitative
Incentives		Qualitative, Quantitative
Infrastructure	Salvage Companies	Quantitative
Deconstruction Expertise		Quantitative
Reuse Businesses		Quantitative
Resale Market		Quantitative
Recycling Market		Quantitative
Societal attitude and status		Qualitative
Waste quantities from demolitions		Quantitative
Waste quantities from renovations		Quantitative
Salvageable quantities from C&D waste stream		Quantitative

At this point it is necessary to distinguish between deconstruction from a contractor perspective and deconstruction as a regional waste reduction strategy.

Deconstruction for Contractors versus Deconstruction for a Region

For the purpose of this research a distinction was drawn between implementing deconstruction on a project (using deconstruction over any other demolition means) and implementing deconstruction as a waste reduction strategy (mandating, regulating, requiring the deconstruction process instead of mechanical demolition). Choosing deconstruction as a structure removal technique on a given project is the responsibility, financially and physically of the contractor. Implementing deconstruction in a region is ultimately the responsibility of the regional officials. The driving force behind implementing this practice for both contractors and regions can come from environmental awareness, regulations, regional necessity, the solid waste management or many other factors. Contractors and regional governments have different priorities and concerns with respect to implementing a new process. Factors that influence the success of the deconstruction process for a contractor may or may not be the same factors that affect the successful implementation of the process on a regional scale.

For example, the deconstruction process takes longer than the traditional demolition process. A structure that may be completely removed in 2 days using traditional mechanical demolition may take 10 days to remove using deconstruction techniques. In this instance, time or project length, may determine if the deconstruction contractor can profit from the project or not. The end result for the region remains the same, the structure is removed and the length of the project does not necessarily impact the region.

Isolating Regional Implementation Specific Variables

This research focuses on the regional implementation of deconstruction, therefore for the purposes of the assessment tool development, these variables were isolated from contractor specific variables. The variables specifically associated with the individual needs of a deconstruction contractors and structure specific details were not considered. This tool was developed from the standpoint that the region wishes to move toward sustainability by better handling the waste generated in the community and more specifically, that generated in the removal of existing single family residential structures. The tool was developed to determine the potential for successful implementation of the deconstruction process at a regional level. In addition to isolating variables that would influence a regional implementation, it was necessary to identify variables that were quantifiable and readily available for documentation.

Upon removal of the structure and contractor dependent variables from consideration , the following preliminary list of variables, shown in Table 3.15, was developed and presented to the research committee prior to the development of the assessment tool. This table became the basis for the development of the assessment tool. The main factors influencing the success of the deconstruction process are the growth occurring in the region, the economic situation of the region and the cost associated with removing the structure, the existing buildings available for removal, the government regulations, the infrastructure available to support the deconstruction process, and the societal attitude toward protecting the environment.

Table 3.15 Preliminary Assessment Tool Variable List.

Influence Factors / **Variables**	**Growth**	**Economy**	**Building Stock**	**Government**	**Infrastructure**	**Society**
Population Growth/rate	X	X	X			
Building Permits	X	X	X		X	
Unemployment Rate	X	X			X	X
Personal Income	X	X			X	X
Building Quantities	X		X	X		
Building Age			X	X		
Building Types			X	X		
Number of Demolitions			X	X		
Number of Renovations			X	X		
Tipping Fees		X		X		X
Demolition Policy				X		
Waste Management				X		
Regulations		X		X		
Incentives		X		X		
Salvage Co.		X			X	
Deconstruction Expertise				X	X	X
Reuse Businesses		X			X	
Resale Market		X			X	X
Recycling Market		X		X	X	X

Summary

The purpose of this chapter was to determine the types and quantity of salvaged materials generated from single family wood frame residential structures, determine the achievable diversion rate, and to assemble a preliminary list of factors influencing the success of implementing deconstruction as a waste reduction strategy.

The most abundant types of materials salvaged were masonry products and wood products. The masonry products consisted of concrete, CMU, and brick. The wood products consisted of dimensional lumber, sheathing, mixed and painted wood, and trim. These two categories of materials were the predominant materials salvaged. The diversion rates reported in residential case studies or calculated from the test area data collected and ranged from 28.20% to 77.60%. The calculated average diversion rate was approximately 67%. A summary of the case study and test area deconstructions may be found in Table 3.10.

The main factors influencing the success of the deconstruction process are the growth occurring in the region, the economic situation of the region and cost associated with removing the structure, the existing buildings available for removal, the government regulations, the infrastructure available to support the deconstruction process, and the societal attitude toward protecting the environment. The factors influencing the deconstruction process will be further developed in the following chapter.

CHAPTER 4
ASSESSMENT TOOL VARIABLES

Introduction

There are many factors that influence the deconstruction process. After identifying these factors it was necessary to determine the variables that would be used to measure each influence factor. Since this assessment tool is intended for use by solid waste managers or individuals responsible for the management of the C&D waste stream, it was necessary to include variables for which data were accessible and understandable to these individuals. The usability of the tool was also a primary concern. For this reason, the assessment tool was broken into six "Sections". Each "Section" contains variables or requires user input and are briefly outlined below.

Section 1 Regional Economics and Growth: This section contains three categories of needed input: Regional Economics, Regional Growth, and Cost of Living.

Section 2 Development Patterns: This section contains two categories of needed input: Existing Development and Current/Future Development.

Section 3 Business Infrastructure: This section contains three categories of needed input: Recycling Businesses, Reuse Businesses, Potential Deconstructors.

Section 4 Available Building Stock: This section contains six categories of needed input: Residential, Public Housing, General Growth Age, Commercial, Industrial, and Military Installations. Only the first three sections will be used in the assessment tool. The other sections were added to accommodate future expansion of the assessment tool.

Section 5 Policy and Incentives: This section contains four categories of needed input: Recycling, Waste Reduction, Permits, and Incentives.

Section 6 Waste Quantities: This section contains two categories of needed input: C&D Waste and Landfill.

Each section is broken into categories. Each category is defined by one or more variables requiring input provided by the user. The six "sections" were established to organize the variables and user input requirements. In this chapter the variables and required user input contained within each section of the assessment tool are described.

Section 1: Regional and Economic Growth

The physical and population growth of a region and its economics can greatly influence the success of the deconstruction process. (Please refer to Appendix A for a list of references used to determine the influence factors and variables for each section of the assessment tool.) In general it is difficult to initiate new processes in regions with a poor economic state. Regional and economic growth is often a driving factor catalyzing new processes, whereas lack of or negative growth can prove detrimental to the implementation of new and innovative processes. As for most new processes, if a regions economic growth is stagnant or the region is experiencing a net outflow of individuals and businesses new processes are difficult if not impossible to promote and implement. Regions experiencing positive growth have a positive influx of individuals, businesses experience growth and consequently, development is needed to provide service for the growing population such as new roads, homes, shopping areas, and schools. Growth may also indicate the presence of increasing job markets and new business development.

Section 1 of the assessment tool contains three categories of needed information each defined by a single variable. The first category is Regional Economics determined by the variable Unemployment Rate. The second category is Regional Growth defined by the variable Population Growth Rate. The third category is Cost of Living, defined by the variable Average Income Per Household.

Unemployment Rate

The overall economic situation plays a key role in implementation. The economics of the region, economics of the people in the region and the economics of businesses are all contributing factors. The unemployment rate is an indicator of these factors. It represents the percentage of the regional population that is unemployed (West and Lenze a, 1999).

Population Growth Rate

This rate indicates the net influx or outflow of individuals in a region (West and Lenze a, 1999). This number is used to determine how quickly or slowly the region is growing. The higher the population growth rate the faster the region is experiencing growth both physically and economically.

Average Income Per Household

The average income per household is an indicator of the relative wealth of the individuals within a region (West and Lenze a, 1999). This number also provides information on the potential quantity of disposable moneys available for non-essential goods.

Section1 Data Accessibility

In addition to identifying variables that would represent the needed input, it was necessary to identify variables that are accessible to the individuals responsible for determining the best waste management options available. The Unemployment Rate, the Population Growth Rate, and the Average Income per Household are quantifiable and accessible through the census web page at www.census.gov if regional data is unavailable.

Section 2: Development Patterns

The current size of the region and the past and planned development for the region are important considerations. (Please refer to Appendix A for a list of references used to determine the influence factors and variables for each section of the assessment tool.) Larger metropolitan areas inherently have several factors that can contribute to the success of the implementation process. For example, existing reuse stores and other business infrastructure, less virgin land available for development, and higher land values. Densely developed regions with little or no virgin land available to support regional growth must reuse or redevelop, such as Japan, if they are to continue to grow. If the region contains mostly undeveloped land there is little incentive to reuse and redevelop existing properties if less expensive land is available.

Section 2 of the assessment tool contains two categories: Existing Development and Current/Future Development. The categories are described below.

Existing Development

The existing development category is used to describe the current development level of the region. Four levels of existing development are used in the prototype tool to indicate the level of development in the majority of the region:

1. Large Metropolitan
2. Small Metropolitan
3. Non-urban
4. Rural

Identifying or delineating the regions size that will be analyzed using the assessment tool is the responsibility of the end-user.

Current/Future Development

This category is used to describe the expected or planned development patterns. There are two basic progressions for future development. One development process involves expanding the boundary of the developed area – sprawl, and the second involves developing within the current boundaries of the region-infill.

Sprawl

Sprawl development requires expansion of the developed region into virgin land. In addition to the construction of new structures by developers, the sprawl growth process requires many additional government services. As development spreads out from existing urban areas, especially at low residential densities, the cost of providing and maintaining public services increases. The regional cost of providing central sewer, water, streets and school to low density development just ten miles away from existing sewer and water facilities and employment centers is dramatically higher than the costs associated with serving higher density residential areas near existing infrastructure (Burchell, 1994). Roads and sewer lines have to be extended, and often, new school, fire stations, and libraries are required. Meanwhile, existing public facilities in the urbanized areas may still have unused capacity (Florida Planning, 1998).

Infill

The infill process involves revitalizing, renovating, and reusing existing or previously developed land. Encouraging revitalization and redevelopment of older communities can provide significant savings for local and regional governments while providing an environment conducive to the implementation of deconstruction.

Deconstruction significantly adds to the environmental benefits of revitalization and infill.

In a study completed by Dr. Robert W. Burchell, *called Eastward Ho! Development Futures: Paths to More Efficient Growth in Southeast Florida* analyzed the costs of this rapidly growing region. The cost of accommodating projected regional growth of 2.4 million people in a region that currently has 5 million residents were estimated. The cost is projected to be more than $10.5 billion over the next 20 years if current "sprawl" development patterns continue into the future. The report suggests that the region has an opportunity to realize a cost savings of nearly $6.15 billion through infill development (Infill development including renovation of existing structures could be a direct source of materials for the deconstruction industry). Infill could result in the preservation of 67,725 total acres of developable land; 52,856 acres of prime farmland and 13,887 acres of fragile environmental lands. Savings of an additional $157 million in waste management capital costs, $135.6 million in sewer capital costs, and $1.54 billion in local road costs could also result from infill.

One example compared sprawl to infill, assuming the same number of people and the same number of jobs. The results were that compact growth, which has a mix of housing types at higher densities, consumed 45 percent less land, and cost 25 percent less for roads, 15 percent less for utilities, 5 percent less for housing, and 2 percent less for other public costs than sprawling development at less than three units per acre (LaFrenier, 1995).

Section 3: Business Infrastructure

The supporting infrastructure plays a key role in the success of deconstruction. (Please refer to Appendix A for a list of references used to determine the influence factors and variables for each section of the assessment tool.) Alternative outlets for salvaged materials must be available to successfully implement deconstruction as a waste reduction strategy. This section contains three categories of needed input: Recycling Businesses, Reuse Businesses, and Potential Deconstructors.

The flow of deconstructed materials mimics the traditional flow of new materials. Traditionally, a material flow consists of resource extraction, to manufacturing, to marketing and distribution. Deconstructed materials must follow a similar pattern, however in this case, the definition of the stages of flow change. Traditional resource extraction, what we think of as mining, for example, is now changed to physically removing materials-deconstructing-to acquire the valuable resources. When thinking of manufacturing, traditionally, we think of changing a raw material into a desirable product. The deconstruction equivalent to manufacturing in this case involves taking the salvaged items and performing repairs, processing, recertification, or adaptation to what society needs. Marketing at this stage is similar to that for new products. The network of businesses, manufacturing enterprises, and building professionals needed to create this flow of materials all dictate the success of the deconstruction process. This process is shown in Figure 4.1

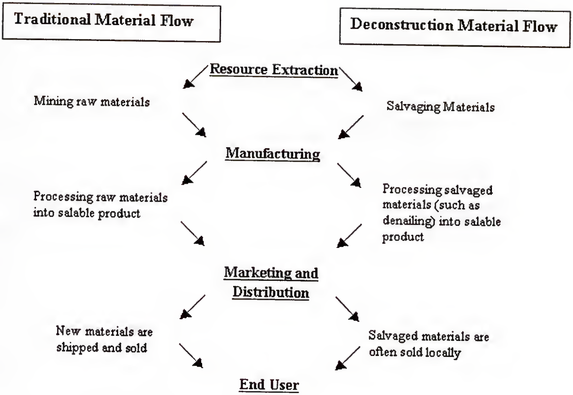

Traditional Material Flow
Deconstruction Material Flow
Resource Extraction
Mining raw materials
Salvaging Materials
Manufacturing
Processing raw materials into salable product
Processing salvaged materials (such as denailing) into salable product
Marketing and Distribution
New materials are shipped and sold
Salvaged materials are often sold locally
End User

Figure 4.1 Material Flow Diagram.

If a process is established to divert and reuse construction materials from landfills, alternative outlets for the materials must exist. If no alternative outlets exist for the materials there is no benefit to implementing the deconstruction process over traditional demolition. With no alternative outlets both the deconstruction and demolition process would result in materials that were landfilled. Administratively requiring the deconstruction process be implemented without a supporting infrastructure would simply place undo financial burden on demolition contractors. Many outlets do exist for materials salvaged from residential structures. One of the keys to increasing the use of alternative material outlets is to increase their convenience, cost competitiveness and accessibility when compared to landfilling. There must be a benefit from separating and removing materials versus simply disposing of the mixed debris that generally results from traditional demolition. Another important factor is the availability of individuals who are willing and able to deconstruct. The deconstruction process is not difficult and most individuals with construction experience can successfully perform deconstructions.

Recycling Businesses

Recycling businesses are an important aspect of creating a process that keeps materials out of landfills. If materials can not be immediately reused, the next most environmentally beneficial step is to recycle them. Recycling can often be a complex process. Some materials are extremely conducive to the recycling process while others can create an environmental hazard when processed. Cost effectiveness of recycling materials also plays a key role in determining which materials are often recycled as well as the number of recycling outlets available. Although there are many materials that result from a residential deconstruction, the largest percentages and the most recyclable materials are wood, metal, and concrete. Since these materials have a steady market it is also likely that recycling businesses would exist. Many other components from residential structures can be recycled, however, their quantities are not large enough to support a business focused specifically on those individual component.

Reuse Businesses

Reuse businesses are also important to divert waste from landfills. The most environmentally friendly option for materials disposal is immediate reuse. Unfortunately this is not always an option, however many materials salvaged from a deconstruction are unique, offer historical value, are innately valuable, or are found in small quantities. Many of these materials have small niche markets or cannot be recycled. Reuse businesses offer outlets for these materials.

Salvage Materials Stores

Salvage material stores are often owned and operated by individuals whom are often contracted to demolish or salvage materials. This allows the salvaged materials to go directly from the removal to resale. These stores can range from a high end antique market to nothing more than an organized junkyard. Their main benefit is that they centralize all of the salvaged materials for consumers.

Habitat for Humanity or Donation Centers

Many salvageable items are not suitable for resale. Lack of value, desirability, or recyclability often would result in the materials being landfilled. Outlets such as Habitat for Humanity provide centers open to donation. Although the salvage contractor may not make a profit from the materials, by donating them, the contractor avoids disposal costs and can receive a tax benefit from the donation.

Used Building Materials Associations

Used Building Material Associations (UBMA) are non-profit, membership-based organizations that represent companies or groups involved in the acquisition and/or redistribution of used building materials. The extension services of these associations often reach a wider audience than local businesses, which allows for more materials to be bought, sold, traded and diverted from landfills. They represent for-profit and non-profit companies and organizations in Canada and the United States that acquire and sell used building materials such as windows, doors, and plumbing fixtures. The UBMA also represent companies that reprocess and recycle building materials such as concrete and asphalt. Their mission is to help companies gather and redistribute building materials in a financially sustainable way.

UBMA Objectives (CIWMB, 1997)

- Provide leadership for the removal of barriers that impede building materials reuse and recycling
- Increase availability of used building materials to the used building materials reuse industry
- Increase public, corporate and government purchase of used or recycled building materials.
- Provide guidance in the set up and operation of building materials reuse/recycling companies
- Develop deconstruction standards, codes of practice and/or guidelines
- Develop educational materials that will help individuals start or increase the efficiency of their building materials' reuse/recycling company
- Lobby governments for legislative change and participate in policy development
- Help develop and promote building materials recycling/reprocessing technologies
- Develop a materials exchange information medium to assist in redistributing and /or acquiring used building materials.

Membership is open to any person who supports the guiding principles and who is the owner, operator, or authorized representative of a business that sells used building materials or that remanufactures or recycles used building materials. Others that have an interest in the industry and wish to support the efforts of the association, such as demolition companies, contractors, or government agencies, but are not directly involved in the industry, may become an association member. Association members have all of the same benefits as members except they may not vote at annual and special meetings.

Similar to the North America's UBMA's the Netherlands have a *Belangenvereniging Recycling Bouw-en Sloopafval (BRBS)* which is their form of a construction and demolition recycling industry association. The members of this association process approximately 95% of all construction and demolition waste that is derived from the construction process (Kowalczyk et al., 1998). The objective of the association is to promote a good infrastructure for disposal of C&D waste and to ensure that materials salvaged for reuse are of high quality. The BRBS promotes the interests of its members and handles the contacts with the authorities and can therefore actively monitor and influence legislation and regulations in this field.

In Canada there are many successful regional operations that sell used building materials. On a larger scale, Happy Harry's Used Building Materials is a good example of how the industry can deal with waste more proactively. Contractor/property manager Harry Bohna founded Happy Harry's in Winnipeg. The company now runs 11 stores across Canada, organized as an owner-operated association. The chain recently opened their first Toronto store, with plans to add another 12 outlets throughout Ontario and Quebec within the next 14 months. The company is affiliated with The National Salvage Network, which enables the company to secure a steady supply of top quality used building materials.

The Salvage Network often works with conventional demolition companies to help recycle and reduce the waste from their projects. The rapid growth of the Happy Harry's retail chain has dramatically increased demand for used building materials, and the company is now aggressively pursuing partnerships with other companies to source materials.

Manufacturing Businesses

Manufacturing enterprises can also use recovered materials to manufacture new products. Items such as reclaimed lumber can serve as the basis for a custom cabinetry manufacturing enterprise. Many materials can, with a little creativity, be reused. The East Bay Center for Creative Reuse in Oakland, CA was started by school teachers to provide a source for low costs artists' supplies. The project opened a reuse center and has since expanded to include artists making art from the salvaged materials and finding high-end markets. Portions of the sales of the art go to supporting the Center. At this time the Center has $15,000 to $16,000 revenues per month.

Potential Deconstructors

The deconstruction process is also dependent on the regional availability of companies and individuals who are qualified and willing to deconstruct. Deconstruction does not require extensive training, however it requires a certain level of finesse to extract materials while maintaining their highest value. Salvage companies and demolition contractors often practice limited deconstruction on every job. Salvage companies, usually hired by the contractor responsible for structure removal, will evaluate the materials to determine what is financially worth the time and energy to reclaim. This process is similar to the building inventory step conducted by deconstructors. Demolition contractors, time permitting, will often salvage high value items prior to mechanical demolition. The shift from partial building component recovery to complete building recovery is not difficult. However, this switch demands time from the contractors, which translates to money. The extra time needed to deconstruct will impact the contractor's profit and therefore not a likely switch.

Section 4: Available Building Stock

There are many reasons structures may be slated for removal. (Please refer to Appendix A for a list of references used to determine the influence factors and variables for each section of the assessment tool.) Building removal may be necessary due to a need for land, damage from a natural disaster, or the buildings having past their useful service lives. The ability to salvage useable materials depends on the type of construction; the materials contained within the structures, and the disassembly techniques available for building removal.

Every year as many as 300,000 buildings are demolished in the United States (NAHB, 1997). On a national level there is not a shortage of structures that can potentially be deconstructed. The shortage occurs in the lack of infrastructure and incentives to support deconstruction activities. Over 100 million housing units exist in the US, most of which are wood-framed. Since the turn of the century, over 3 trillion board feet of lumber and timber have been sawn in the US, and much of it still resides in existing structures (Falk, 1999). Nationally, 7,000 units of public housing and over 100,000 privately owned homes are demolished each year (Snyder,1998). Many of these structures could be deconstructed, creating a supply of building materials for reuse/recycling versus adding of tonnage to the C&D waste stream. Opportunities for deconstruction exist in practically every community in the US. Virtually all houses constructed prior to World War II are candidates for deconstruction due to the quality of materials used and the methods used to construct them. (Hendricks, 1998).

It is difficult to predict the type, size and age or number of structures that may become available for deconstruction during any given time period (CCE, 1998). In looking at the demolition and deconstruction industry it is important to identify the feedstock for this industry. Nationally, regionally, and locally building types vary drastically. The building stock also varies based on classification-i.e. industrial, residential, or commercial. Availability of buildings is not the issue so to speak; it is the availability of buildings worth being deconstructed. Therefore it is important to conduct a survey of the structures types within the region to establish the available building inventory for deconstruction.

Section 4 of the assessment tool contains a total of six categories: Residential, Public Housing, General Growth Age, Commercial, Industrial, and Military Installations. Only the first three categories are used in this prototype assessment tool.

Residential

The three main residential construction types are wood, concrete, and steel frame construction. Non destructive building component salvage is possible in wood frame construction allowing for a higher percentage of direct reuse. Concrete structures must be mechanically removed and direct reuse is limited but recycling crushed concrete is gaining in popularity. Little data is available on steel frame residential reuse, however, due to the nature of steel, high recycling percentages would be expected.

Public Housing

Across the nation, an estimated 200,000 public housing units will be demolished as a result of HOPE VI. For example, the City of Chicago plans to demolish 11,000 apartments, nearly 40 percent of its public housing stock for families, over the next 15 years (Leroux and Seldman, 1999). Public housing may provide buildings for deconstruction with possible government grant assistance.

General Growth Age

The age of structures as well as the component materials can influence decision to restore or remove structures. There are two general trends. First, as the buildings age increases, the likelihood of desirable materials increases. For example, aged structures that contain old growth timbers. Second, as the age of structures increase the more likely they may be protected by historical societies. In general newer structures do not yield the high quality materials often sought after by salvagers.

Other Structure Types

Other structure types were not specifically addressed in this research but it is important to note that all structures are potential building stock for the deconstruction process. The prototype assessment tool can accommodate future expansion of the following structure types.

Commercial Structures

As businesses grow or as businesses close, the removal or renovation of these structures becomes necessary. In general, most commercial structures are steel and concrete. The component breakdown of materials and the overall quantity of materials reclaimed from these structures is significantly different than that reclaimed from residential structures.

Industrial Structures

The progression of technology has rendered many industrial structures outdated. These older buildings also contain valuable materials. However, these structures are often stripped on the interior leaving only the structural skeleton which is easy to remove.

US Military Bases

Hundreds of military bases across the country are being closed or realigned and converted to civilian uses. Redeveloping these properties often requires buildings to be removed because they are obsolete or inconsistent with reuse plans. Many structures on military bases do not meet standard building codes and must therefore be removed or rehabilitated to protect public safety. Deconstruction, which has already begun on some military bases, can help the military reach a 40% solid waste reduction goal. The 40%

goal was scheduled to be introduced by the Department of Defense in 1999 (Center for Economic Conversion, 1997). The military is encouraging deconstruction, salvage, and reuse.

Section 5: Policy and Incentives

Often policy can promote and drive the implementation of new processes in spite of all other factors. (Please refer to Appendix A for a list of references used to determine the influence factors and variables for each section of the assessment tool.) Following money considerations, the influences most often heard from business are regulations, mandates, and laws. Without a legal or an economic push to reduce, reuse and recycle the effort is often ignored. For example, looking at two deconstructions, one in Germany and one in France. These cases show the importance of legislation for implementing this waste reduction strategy. The case studies were conducted to examine the technical and economic feasibility of deconstruction

The structure located in Dobel, Germany was wood framed and the second, located in Mulhouse, France was brick. Half of each structure was deconstructed and half was demolished using traditional methods. As would be expected, the study showed a higher percentage of reusable materials resulted from deconstruction. However, analyses of the costs confirm the importance of local legislation, recycling prices, and disposal prices. The Dobel project-an area with stricter disposal regulation-showed selective deconstruction was more profitable than conventional demolition. In Mulhouse, where disposal regulations are more lenient, deconstruction was twice as expensive as traditional demolition.

Incentives play an important role in the implementation process. Incentives may act as a catalyst promoting the deconstruction process in spite of or in addition to policy. If policy promoting deconstruction is in place, incentives can act to ease the potential financial burden faced by business owners implementing a new process. If policy is not in place, incentives may act as the only perceived benefit of implementation.

Recycling

As environmental concerns have come into public focus, many regions have turned to mandate recycling as their local environmental saviors. The first step for most areas is to either begin recycling at the local landfills or to implement a curbside recycling programs. A progressive step towards implementing sustainable practices to require or mandate recycling.

Waste Reduction

Many regions combine their waste reduction and recycling programs when, indeed, the two processes are distinctly different. These processes are often confused because the measurement that accounts for waste reduction is almost always measured at the landfill. Implementing recycling programs allow for less waste to be landfilled but they do not reduce the waste that is generated. As explained in the waste management hierarchy, reduction is a more environmentally friendly alternative. The reduction practice should require that the total waste generated be reduced, not just the quantity ending in the landfills.

Permits

Many, but not all, local building jurisdictions require demolition permits or formal notification of intent to remove a building. The permitting process allows the local government to monitor the types and number of demolitions occurring in the region.

This also allows the region to protect any potentially historical buildings from destruction. Permits also provide the opportunity for the region to require waste management plans or mandate a recycling percentage to reduce the waste generated from demolition sources.

Incentives

Incentives can act to promote more sustainable waste management. There are several types of incentives such as monetary, regulatory, or environmental. Unfortunately the majority of contractors will not find the incentive to protect the environment as reason enough to implement a new process. Regulatory or monetary incentives are often needed to promote the deconstruction process as they may change their competitive position. For example, requiring a waiting period for demolition permits while allowing deconstruction to begin immediately may act as an incentive if the contractor is under a tight schedule. In this instance time is used as an incentive to promote the deconstruction process. It is possible that completing the project in a faster time period could compensate any financial burden the contractor faces from implementing the deconstruction process.

Section 6: Waste Quantities

The priority placed on reducing the C&D waste stream will depend on the extent of the burden felt by the solid waste managers. (Please refer to Appendix A for a list of references used to determine the influence factors and variables for each section of the assessment tool.) If there is an unlimited resource of landfills with low tipping fees and a minimal amount of waste generated, there is little incentive to promote new waste reduction programs. In this instance, there is little burden placed on the solid waste management professionals. If there is limited landfill space and a large quantity of waste, a higher priority may be placed on proper disposal of the waste stream.

This section contains two categories of needed input: C&D Waste and Landfill. The first steps of implementing the deconstruction process is determining the magnitude of the regional C&D waste and committing to reduce the waste stream.

C&D Waste

Unfortunately there is no unified or common method for collecting data on the quantity of C&D waste generated. Many regions do not collect any data at all on C&D waste and those that do have developed in-house procedures to quantify the waste stream. Fewer and fewer governments are retaining control over waste handling operations. As private companies take over the waste handling business, accurate public record of the processes lessen. Organizing and using information that most regions may already have access to is an important aspect of determining the need for implementing waste reduction strategies.

Total Annual Waste

The total annual waste is the total waste stream for the region. This waste stream usually contains both the municipal solid waste tonnage and the C&D tonnage. The amount of residential demolition and renovation waste generated annually may be derived from the total annual waste quantity.

Total C&D Waste

Many regions do not collect data on the C&D waste stream. If the total C&D waste is known, this data can be used to provide a more accurate determination of the potential deconstruction has to reduce the waste stream.

Residential Demolition Permits

The square footage of residential demolitions permitted can be used to determine the total tonnage of regional C&D waste. This data is dependent on the methods used to collect data in a specific region. Unfortunately this number may not necessarily indicate any regional renovations as most home renovation projects do not require permits.

Landfill

The availability, number, and expected longevity of landfills in a given region can influence the burden experienced by solid waste managers. These factors influence the importance of reducing or finding other outlets for waste.

Number of Landfills

In general as the number or readily available landfills decrease or the distance to the landfills increase, contractors are forced to find alternative methods of disposal. The greater the number of locally available landfills the more likely contractors will choose to use them. Regions lacking local landfills must either pay the cost to transport waste, or implement waste reduction plans to limit the cost of disposal.

Expected Life of Landfills

The total capacity of the landfill and the rate the landfill is filling determines the number of years that remain in the life of the landfill. Due to regulations, the cost of sitting a new landfill and landfill capacity, the number of open landfills is declining. The expected life of the landfill defines the time constraint placed by the solid waste managers to find alternative disposal sites or options.

Tipping Fees

The tipping fees are the amount paid to the landfill to dispose of materials. The tipping fees are usually paid per ton or per load and can vary significantly from less than $5.00 to over $100.00 per ton depending on the region (Repa, 1993).

Additional Influence Factors

Several factors although important to the deconstruction practice were not used in this assessment tool. These variables were found to be dependent on many other factors and did not contribute to the clarification of determining a successful implementation versus an unsuccessful implementation.

These factors are all important for the success of the deconstruction process to a deconstructor or contractor but not necessarily to the overall regional goals of implementation. Other factors may seem important but may be related to a specific project and not to the large scale implementation while other such as "market" are not predictable at this time and are thus not included in the prototypes.

Market

The regional market existing for salvaged materials can play a key role in the success of the deconstruction process. The wide variety of buildings available for deconstruction provides a variety of materials produced from their disassembly. The unsure quality and quantity of these used building materials means that users cannot rely on a constant and consistent supply. Unfortunately, since the materials reclaimed from deconstructions are not constant, determining the existing market is difficult. The salvaged materials markets are pedestrian dependant. Personal preference, beliefs, and concern for the environment all dictate an individual's willingness and acceptance of using salvaged materials. The dominant mindset regarding building materials is centered around the concept "newer is better". The reclaimed items that are highly desirable such as old growth timber tend to exceed many individuals price ranges.

The market variable is represented in Section 3, Business Infrastructure. This section requires the user to input information on the number of recycling and reuse businesses available. In regions were there was no market for these materials the number of existing businesses would be low. If the region contains a market demanding reclaimed materials, the number of businesses would be expected to be high.

Labor

The deconstruction process is much more labor intensive than the traditional demolition process. Labor costs are typically the largest portion of a deconstruction budget. The labor cost variable is based on several factors such as the size and type of structure, the skill level of the crew, prevailing wage rate, and how easily the materials can be removed. Labor rates vary greatly from region to region as well as within a given region. The cost of labor may depend on the skill of the crew and the given demand for manual laborers at any given time.

The labor variable is represented in Section 1: Regional and Economic Growth. For the overall success of implementing deconstruction on a regional level, it is more important that the individuals have what is termed "disposable cash". An amount of excess funds above and beyond the income needed to provide necessities. The "disposable cash" increases the ability to market, move, and purchase the reclaimed materials. The availability of disposable cash outweighs the need for low labor rates. Regions with extremely low labor rates would benefit a deconstruction contractor, since deconstruction is a very labor-intensive process, however few individuals may have the funds to purchase salvaged materials. The overall economic health of the region is important to implementation.

Land Value

The price or value of land within a region can influence the growth patterns and the ability to purchase land for new landfills. Land values vary greatly throughout the country as well as within a given region. High land values in many cases indicate little new land is available for new development which will promote the infill process.

This variable is represented in Section 1: Regional and Economic Growth and Section 2: Development Patterns.

Summary

The factors influencing the deconstruction process as well as the waste management process were identified and categorized into six sections. These six sections are listed below:

Section 1: Regional and Economic Growth
Section 2: Development Patterns
Section 3: Business Infrastructure
Section 4: Available Building Stock
Section 5: Policy and Incentives
Section 6: Waste Quantities

Each section contains several categories of influence factors and each category of influence factors contains one or more variable or question requiring user input. Chapter 5 discusses the specifics involved in developing the assessment tool for use by solid waste managers and provides further clarification of the required user input.

CHAPTER 5
DECONSTRUCTION ASSESSMENT TOOL

Introduction

The task of turning the categories of influence factors developed from the case studies and the physical deconstructions into a usable tool for solid waste managers consisted of 5 key phases as listed below.

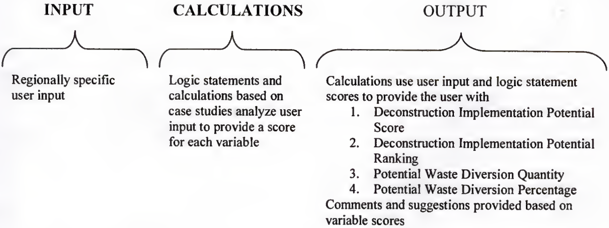
1. Identify the specific variables for user input
2. Design a user interface
3. Develop a scoring system
4. Evaluate the user input
5. Provide output for the user

Each of the six "sections" identified in Chapter 4 contains several influence factors. Whenever possible a single variable was used to quantify the influence factor. The assessment tool uses both variables and questions the user must answer to evaluate the region. This chapter discusses the mechanical development and layout of the assessment tool, programming the tools functions, scoring each variable, and the evaluation process. Each "section" of the assessment tool is shown in Figures 5.4 – 5.11 and 5.13. In addition, this chapter also contains a complete demonstration, Figures 5.14 through 5.27. This chapter also discusses the industry contacts and testing procedure used to evaluate the assessment tool.

Assessment Tool Overview

The user is responsible for entering the data required in the six sections of the assessment tool. The user input is analyzed by a series of logic statements producing scores for each of the variables. The scores and user input are used in calculations resulting in the Deconstruction Implementation Potential Score, Deconstruction Implementation Potential Ranking, the potential waste diversion quantity, and the potential waste diversion percentage. The variable scores and user input are then evaluated by the assessment tool to provide regionally specific information, comments and suggestions to the user that may be used to assist in the planning and the decision making process for improving the regions Deconstruction Implementation Potential Score.

The basic components of the assessment tool are shown in Figure 5.1. The desired output for the assessment tool was to provide the individuals responsible for solid waste management with a ranking that establishes the potential for successfully implementing deconstruction as a waste reduction strategy. This ranking, if high, could be used to encourage deconstruction implementation, a low ranking would indicate the region should pursue waste management options other than or in conjunction with deconstruction. In addition to providing a regional ranking the goal was to provide comments based on the regions user input to assist the user with improving their potential to successfully implement deconstruction.



INPUT

Regionally specific user input

CALCULATIONS

Logic statements and calculations based on case studies analyze user input to provide a score for each variable

OUTPUT

Calculations use user input and logic statement scores to provide the user with

1. Deconstruction Implementation Potential Score
2. Deconstruction Implementation Potential Ranking
3. Potential Waste Diversion Quantity
4. Potential Waste Diversion Percentage

Comments and suggestions provided based on variable scores

Figure 5.1 Assessment Tool Components

User Interface Development

The assessment tool is designed to evaluate any region and therefore the tool has to support a wide variety of user input. In addition to accepting user input, the tool must be user friendly and therefore was designed using widely available software. The tool was developed using Microsoft Excel and Visual Basic. Microsoft Excel offers several advantages. Most importantly, Excel allows for user input and evaluation of this input. It was necessary to evaluate and score the user input. The scored user input is used in the calculations and output sections of the assessment tool.

Assessment Tool Layout

The Excel file includes a total of 17 worksheets. The first worksheet is the introduction, worksheet 2 through 7 are used for user input and logic statement that convert the user input into numeric values for the calculations. The 8th sheet is used to calculate the output scores – using the numeric values and user entered data from worksheets 2 through 7. Worksheets 9 through 14 provide output for the user in the form of comments, suggestions and recommendations. The assessment tool contains 2 additional worksheets. One worksheet is dedicated to providing information to assist Florida users with Section 1 of the assessment tool. The Florida specific database was included as a test section to provide the Florida based recycling coordinators and solid waste managers easy access to the input needed for Section 1 of the assessment tool. The second worksheet is a hidden worksheet and contains a database of recommendations used for worksheets 9 through 14. The introduction, Florida database, calculations, and comment database worksheets require no user input.

When the user opens the assessment tool file, they are on the introduction page. The links developed between the worksheets within the assessment tool prompt the user to proceed through the 6 user input sections to the calculations and recommendation portion of the assessment tool. The worksheet links are shown in Figure 5.2.

Throughout the assessment tool, “Buttons” have been placed to prompt the user through the assessment tool. The “Buttons” are “clickable” objects with corresponding macros performing programmed operations. For example, the button with the words “Proceed to Section 2” when clicked, will take the user to Section 2 of the assessment tool.

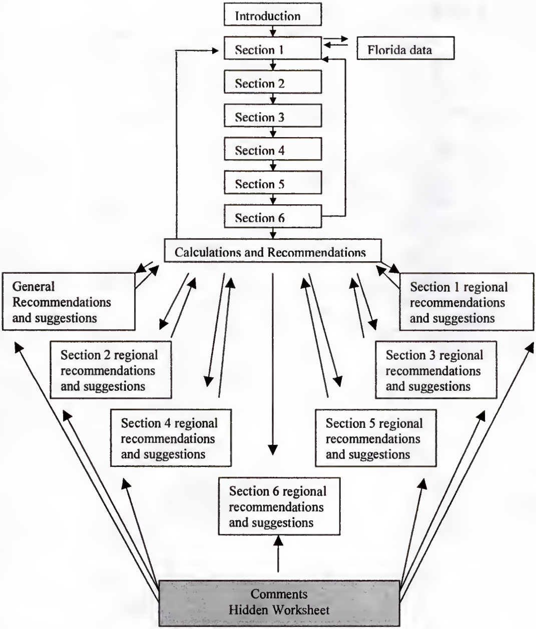

Introduction
Section 1
Florida data
Section 2
Section 3
Section 4
Section 5
Section 6
Calculations and Recommendations
General Recommendations and suggestions
Section 1 regional recommendations and suggestions
Section 2 regional recommendations and suggestions
Section 3 regional recommendations and suggestions
Section 4 regional recommendations and suggestions
Section 5 regional recommendations and suggestions
Section 6 regional recommendations and suggestions
Comments Hidden Worksheet

Figure 5.2 Assessment Tool Worksheet Links

Once the user has proceeded through the user input sections the user may calculate the scores and proceed to the comments sections. Excel provides user interface level programmed function – the menus and dialog boxes – to perform preprogrammed tasks. These programmed functions alone would not perform the needed analysis process. Excel, however, can be programmed outside its standard applications using

Visual Basic for Applications (VBA). Although the assessment tool is presented in Microsoft Excel, all of the processes contained within the Assessment tool were programmed in VBA to create the resulting working Deconstruction Implementation Assessment Tool.

The macros that actually drive the Assessment tool are programmed in Visual Basic. An example of one of the VBA programs follow in Figure 5.3. This program drives the "button" to calculate the Deconstruction Implementation Potential Score. Microsoft Visual Basic manages each of the programs needed to run the Excel macros that drive the complete working assessment tool.

```
Sheets("1").Select  Range("F3:F5").Select  Selection.Copy  Range("G3:G5").Select Selection.PasteSpecial
Paste:= xlValues, Operation:=xlNone, SkipBlanks:= _  False, Transpose:=False  Sheets("2").Select
Range("F4").Select  Application.CutCopyMode = False  Selection.Copy  Range("G4").Select  Selection.
PasteSpecial  Paste:=xlValues, Operation:=xlNone, SkipBlanks:= _  False, Transpose:=False  Range
("F6:F7").Select   Application.CutCopyMode = False   Selection.Copy   Range("G6:G7").Select
Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, SkipBlanks:= _      False, Transpose:=False
Sheets("3").Select   ActiveWindow.SmallScroll Down:=-18   Range("F4:F6").Select  Application.
CutCopyMode = False   Selection.Copy   Range("G4:G6").Select Selection. PasteSpecial Paste:=
xlValues, Operation:=xlNone, SkipBlanks:= _      False, Transpose:=False  Range("F8:F14"). Select
Application.CutCopyMode = False   Selection.Copy   ActiveWindow.SmallScroll Down:=-3 Range
("G8:G14").Select   Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone, SkipBlanks:= _ False,
Transpose:= False   ActiveWindow.SmallScroll Down:=3   Range("F16:F17").Select  Application.Cut
CopyMode = False   Selection.Copy   Range("G16:G17").Select   Selection.PasteSpecial Paste:=
xlValues, Operation:=xlNone, SkipBlanks:= _ alse, Transpose:=False   Sheets("4").Select  Range("F4:F6")
.Select   Application.CutCopyMode = False   Selection.Copy   Range("G4:G6").Select  Selection.Paste
Special Paste:=xlValues, Operation:=xlNone, SkipBlanks:= _      False, Transpose:=False ActiveWindow
.SmallScroll Down:=3   Range("F9:F10").Select  Application.CutCopyMode = False   Selection.Copy
Range("G9:G10").Select   Selection.PasteSpecial Paste:= xlValues, Operation:=xlNone, SkipBlanks:= _
False, Transpose:=False   Sheets("5").Select  ActiveWindow. SmallScroll Down:=-15 Range("F3:F13").
Select   Application.CutCopyMode = False   Selection.Copy  Active Window.SmallScroll Down:=-12
Range("G3:G13").Select   Selection.PasteSpecial Paste:=xlValues, Operation: =xlNone, SkipBlanks:= _
False, Transpose:=False   Sheets("6").Select   Range("F3:F5").Select  Application.Cut CopyMode = False
Selection.Copy   Range("G3:G5").Select   Selection.PasteSpecial Paste:=xlValues, Operation: =xlNone,
SkipBlanks:= _      False, Transpose:=False   Range("F7:F9").Select   Application.CutCopyMode = False
Selection.Copy   Range("G7:G9").Select   Selection.PasteSpecial Paste:=xlValues, Operation:=xlNone,
SkipBlanks:= _      False, Transpose:=False   Sheets("7-DIPS").Select   Range("B3").Select  ActiveCell.
FormulaR1C1 = _
"='1'!R[4]C[5]+'2'!R[7]C[5]+'3'!R[15]C[5]+'4'!R[14]C[5]+'5'!R[11]C[5]+'6'!R[7]C[5]"
Range("B4").Select   Range("B4").Select   ActiveCell.FormulaR1C1 = _
"='1'!R[3]C[4]+'2'!R[6]C[4]+'3'!R[14]C[4]+'4'!R[13]C[4]+'5'!R[10]C[4]+'6'!R[6]C[4]"
Range("B4").Select         End Sub
```

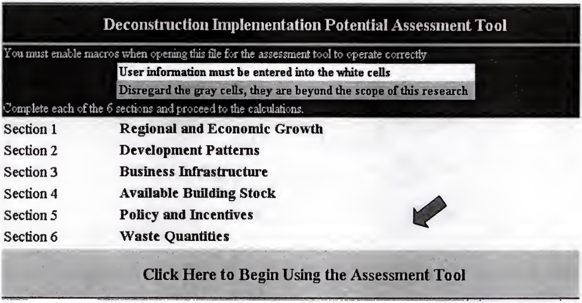
Figure 5.3 Sample Macro Program for Calculating the DIPS.

The DIAT contains a total of 30 macro driven "buttons" allowing the user to "click" to proceed throughout the assessment tool. Each of the "buttons" requires a VBA program similar to the above to operate. The three phases; user input, calculations and output sections of the assessment tool and their development are discussed below.

User Input Sections Assessment Tool Worksheets 1-7

Worksheet 1 – Introduction

The introduction sheet was created to provide the user with a brief introduction, basic instructions, and a table of contents for the assessment tool. When the assessment tool was distributed, it was accompanied by a narrated, automated PowerPoint presentation that describes the deconstruction process, the scope of the research, and detailed directions for using the assessment tool. Figure 5.4 shows the introduction page of the assessment tool.



Deconstruction Implementation Potential Assessment Tool

You must enable macros when opening this file for the assessment tool to operate correctly

User information must be entered into the white cells

Disregard the gray cells, they are beyond the scope of this research

Complete each of the 6 sections and proceed to the calculations.

Section 1	Regional and Economic Growth
Section 2	Development Patterns
Section 3	Business Infrastructure
Section 4	Available Building Stock
Section 5	Policy and Incentives
Section 6	Waste Quantities

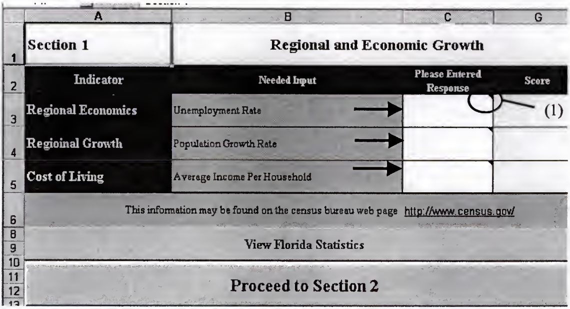
Click Here to Begin Using the Assessment Tool

Figure 5.4 Assessment Tool Introduction

All user information is entered into white cells throughout the assessment tool. All other cells contain a colored background. This was done for visual reasons, making the white cells stand out and easily identifiable by the users. All of the colored cells in the spreadsheet have been locked so the user will not accidentally delete any portion of the assessment tool. The assessment tool also contains several dark gray cells (in Section 4) which are sections beyond the scope of this research. These sections were added to allow for future expansion of the assessment tool. To begin using the assessment tool, the user must "click" on the gray button at the bottom of the page, marked with an arrow in Figure 5.4. When the user "clicks" the "begin using assessment tool" button they are taken to Section 1 of the assessment tool.

Worksheet 2 – Section 1

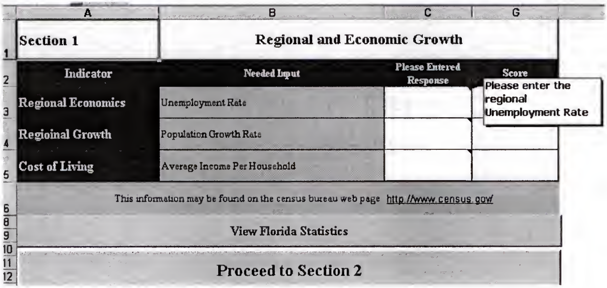
Section 1 is the first section that requires user input. This section contains 3 fields – white cells-that require user input and are shown in Figure 5.5 with arrows.



	A	B	C	G
1	**Section 1**	**Regional and Economic Growth**		
2	Indicator	Needed Input	Please Entered Response	Score
3	Regional Economics	Unemployment Rate		
4	Regioinal Growth	Population Growth Rate		
5	Cost of Living	Average Income Per Household		
6	This information may be found on the census bureau web page http://www.census.gov/			
8 9	View Florida Statistics			
10 11 12	Proceed to Section 2			

Figure 5.5 Assessment Tool Section 1

All cells with a red upper right hand corner (shown as (1) in Figure 5.5) are a link to comments to assist the user. When the user moves the cursor to the cell with a red upper right corner, a comment appears to assist the user in inputting data as seen in Figure 5.6.



Section 1	Regional and Economic Growth		
Indicator	Needed Input	Please Entered Response	Score
Regional Economics	Unemployment Rate		
Regioinal Growth	Population Growth Rate		
Cost of Living	Average Income Per Household		

Please enter the regional Unemployment Rate

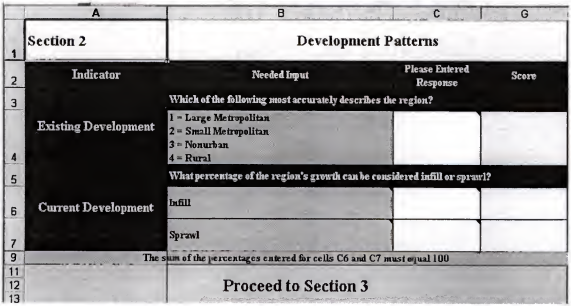
This information may be found on the census bureau web page http //www.census.gov/

Figure 5.6 Assessment Tool Section 1 with comments

A hyperlink to the census web page is been provided to assist the user in determining the user required information if it is not known. If the users are in the State of Florida, county-specific information has been provided and may be accessed by clicking in the "View Florida Statistics" button. A "button" is also provided so the user may proceed to the next section.

Worksheet 3 – Section 2

Section 2 requires 3 fields of user input on existing and current development patterns. Once the user has completed the required information, a button is provided to continue to the next section. Figure 5.7 shows Section 2 of the assessment tool.



	A	B	C	G
1	Section 2	Development Patterns		
2	Indicator	Needed Input	Please Entered Response	Score
3		Which of the following most accurately describes the region?		
4	Existing Development	1 = Large Metropolitan 2 = Small Metropolitan 3 = Nonurban 4 = Rural		
5		What percentage of the region's growth can be considered infill or sprawl?		
6	Current Development	Infill		
7		Sprawl		
9	The sum of the percentages entered for cells C6 and C7 must equal 100			
11				
12		Proceed to Section 3		
13				

Figure 5.7 Assessment Tool Section 2

Worksheet 4 – Section 3

Section 3 requires user input on the existing businesses available in the region. This section is somewhat different from the previous sections because it contains several questions that require "yes" or "no" responses. Figure 5.8 shows Section 3. At the bottom of section 3 the user is prompted to continue to the next section.

Worksheet 5 – Section 4

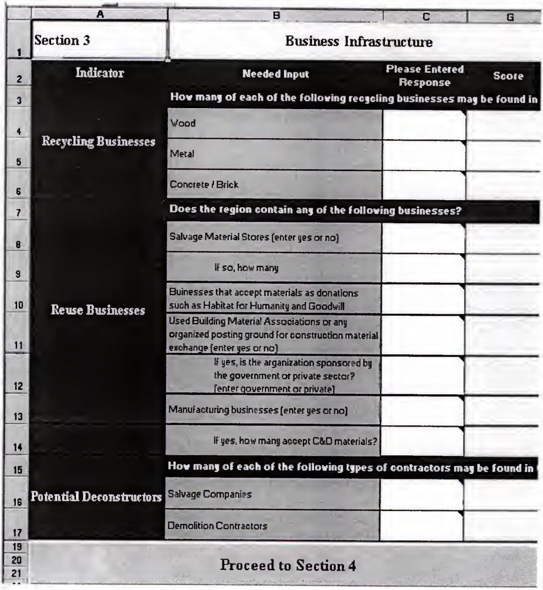
Section 4 requires user input on "available building stock". This assessment tool is limited to input for residential structures, however the assessment tool was designed to accommodate future expansion to include commercial, industrial, and military structures as shown in Figure 5.9. After completing this section the user proceeds to the Section 5.

Worksheet 6 – Section 5

Section 5 is similar to Section 3 in that it asks the user questions versus requiring direct user input as seen in Figure 5.10. This section collects information on the regions policies and incentives and prompts the user to proceed to the next section.

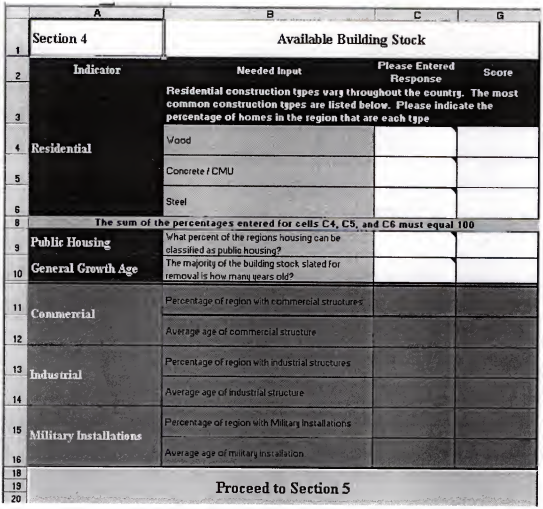
Worksheet 7 – Section 6

Section 6 is the last section requiring user input. This section requires information on the waste stream and landfills in the region as seen in Figure 5.11. After completing this section the user may either review all previous sections or proceed to the calculations portion of the assessment tool.



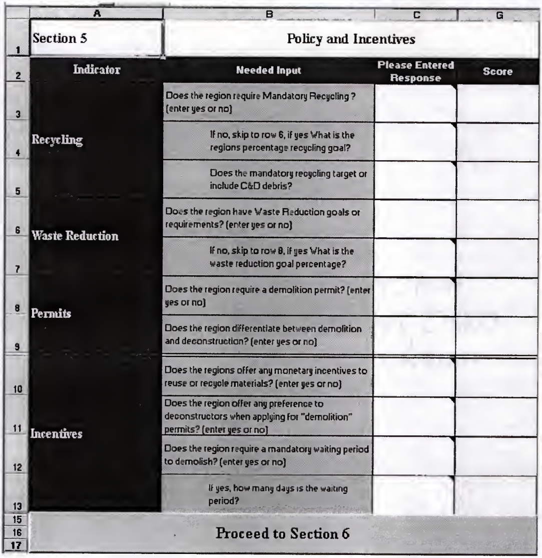
	A	B	C	G
1	Section 3	Business Infrastructure		
2	Indicator	Needed Input	Please Entered Response	Score
3		How many of each of the following recycling businesses may be found in		
4	Recycling Businesses	Wood		
5		Metal		
6		Concrete / Brick		
7		Does the region contain any of the following businesses?		
8		Salvage Material Stores (enter yes or no)		
9		If so, how many		
10	Reuse Businesses	Buinesses that accept materials as donations such as Habitat for Humanity and Goodwill		
11		Used Building Material Associations or any organized posting ground for construction material exchange (enter yes or no)		
12		If yes, is the arganization sponsored by the government or private sector? (enter government or private)		
13		Manufacturing businesses (enter yes or no)		
14		If yes, how many accept C&D materials?		
15		How many of each of the following types of contractors may be found in		
16	Potential Deconstructors	Salvage Companies		
17		Demolition Contractors		
19 20 21	Proceed to Section 4			

Figure 5.8 Assessment Tool Section 3



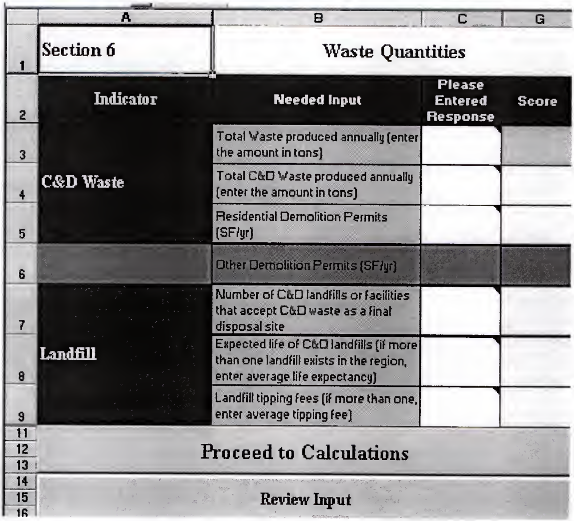
	A	B	C	G
1	Section 4	Available Building Stock		
2	Indicator	Needed Input	Please Entered Response	Score
3		Residential construction types vary throughout the country. The most common construction types are listed below. Please indicate the percentage of homes in the region that are each type		
4	Residential	Wood		
5		Concrete / CMU		
6		Steel		
8	The sum of the percentages entered for cells C4, C5, and C6 must equal 100			
9	Public Housing	What percent of the regions housing can be classified as public housing?		
10	General Growth Age	The majority of the building stock slated for removal is how many years old?		
11	Commercial	Percentage of region with commercial structures		
12		Average age of commercial structure		
13	Industrial	Percentage of region with industrial structures		
14		Average age of industrial structure		
15	Military Installations	Percentage of region with Military Installations		
16		Average age of military installation		
18				
19	Proceed to Section 5			
20				

Figure 5.9 Assessment Tool Section 4



	A	B	C	G
1	Section 5	Policy and Incentives		
2	Indicator	Needed Input	Please Entered Response	Score
3	Recycling	Does the region require Mandatory Recycling ? (enter yes or no)		
4		If no, skip to row 6, if yes What is the regions percentage recycling goal?		
5		Does the mandatory recycling target or include C&D debris?		
6	Waste Reduction	Does the region have Waste Reduction goals or requirements? (enter yes or no)		
7		If no, skip to row 8, if yes What is the waste reduction goal percentage?		
8	Permits	Does the region require a demolition permit? (enter yes or no)		
9		Does the region differentiate between demolition and deconstruction? (enter yes or no)		
10	Incentives	Does the regions offer any monetary incentives to reuse or recycle materials? (enter yes or no)		
11		Does the region offer any preference to deconstructors when applying for "demolition" permits? (enter yes or no)		
12		Does the region require a mandatory waiting period to demolish? (enter yes or no)		
13		If yes, how many days is the waiting period?		
15	Proceed to Section 6			
16				
17				

Figure 5.10 Assessment Tool Section 5



	A	B	C	G
1	Section 6	Waste Quantities		
2	Indicator	Needed Input	Please Entered Response	Score
3	C&D Waste	Total Waste produced annually (enter the amount in tons)		
4		Total C&D Waste produced annually (enter the amount in tons)		
5		Residential Demolition Permits (SF/yr)		
6		Other Demolition Permits (SF/yr)		
7	Landfill	Number of C&D landfills or facilities that accept C&D waste as a final disposal site		
8		Expected life of C&D landfills (if more than one landfill exists in the region, enter average life expectancy)		
9		Landfill tipping fees (if more than one, enter average tipping fee)		
11 12 13	Proceed to Calculations			
14 15 16	Review Input			

Figure 5.11 Assessment Tool Section 6

Calculations-Scoring the User Input

Due to the variability of user input it was necessary to develop a ranking system for all possible user input to normalize the scores. The user input is evaluated using logic statements to give each variable a score from 0 to 5. The logic statements perform a series of true false tests. The statement returns one value if the specified condition is true and another value if the specified condition is false. The format of the logic statements follow; IF(logical_test,value_if_true,value_if_false). For example, the logic statement associated with the Unemployment Rate example is =IF(C3>6,"1",IF(C3>5,"2",IF(C3>4,"3",IF(C3>3,"4","5")))) as shown in Table 5.1

The "Logical_test" is any value or expression that can be evaluated to TRUE or FALSE. For example, C3>6 is a logical expression; if the value in cell C3 is greater than 6, the expression evaluates to TRUE. Otherwise, the expression evaluates to FALSE. The "Value_if_true" is the value that is returned if logical_test is TRUE. For example, if C3>6, the argument returns a "1". The "Value_if_false" is the value that is returned if logical_test is FALSE. In this example, if the test is false, another logic test is performed. The value in the cell C3 is evaluated by a second logical_test, (C3>5), if this statement is true, the argument returns a "2", if false, a new logic test is performed. This continues until all of the logic tests are complete and a score is returned.

Each logic test has an individual scale for scoring user input. Most of the variables are scored on a linear scale. The scoring scales were determined based on case studies, lessons learned from C&D waste management studies, deconstruction data, interviews with deconstruction experts, and solid waste management professionals. In instances where available data permitted more accurate scoring, the assessment tool was adjusted to accommodate specific scoring values. The use of a zero as an output score was limited as not to discourage the users from pursuing the deconstruction alternative. The logic statements for each variable contained in the assessment tool are shown the Table 5.1. Each logic statement differs dependent on the variable and possible user input.

Table 5.1 Assessment Tool Scoring Logic.

Indicator	Variable	Scoring Logic
Section 1: Regional and Economic Growth		
Regional Economics	Unemployment Rate	=IF(C3>6,"1",IF(C3>5,"2",IF(C3>4,"3",IF(C3>3,"4","5"))))
Regional Growth	Population Growth Rate	=IF(C4>4,"5",IF(C4>3,"4",IF(C4>2,"3",IF(C4>1,"2","1"))))
Cost of Living	Average Income Per Household	=IF(C5>100000,"5",IF(C5>75000,"4",IF(C5>50000,"3",IF(C5>25000,"2","1"))))
Section 2: Development Patterns		
Existing Development	1 = Large Metropolitan 2 = Small Metropolitan 3 = Nonurban 4 = Rural	=IF(C4=1,5,IF(C4=2,4,IF(C4=3,2,IF(C4=4,1,""))))
Current Development	Infill	=IF(C6>84,5,IF(C6>64,4,IF(C6>44,3,IF(C6>24,2,1))))
	Sprawl	=IF(C7>74,"1",IF(C7>59,"2",IF(C7>44,"3",IF(C7>29,"4","5"))))
Section 3: Business Infrastructure		
Recycling Businesses	Wood	=0.4243*C4
	Metal	=0.0706*C5
	Concrete/Brick	=0.2402*C6
Reuse Businesses	Salvaged Materials Stores	=IF(C8="yes",1,IF(C8="no",0,""))
	How many	=0.753*C9
	Habitat for Humanity	=IF(C10="yes",1,IF(C10="no",0,""))
	Used Building Materials Associations	=IF(C11="yes",1,IF(C11="no",0,""))
	Government or private	=IF(C12="private",4,IF(C12="government",5,""))
	Manufacturing Businesses	=IF(C13="yes",1,IF(C13="no",0,""))
	How many	=C14
Potential Deconstructors	Salvage Companies	=C16
	Demolition Contractors	=C17
Section 4: Available Building Stock		
Residential	Wood	=IF(C4>79,"5",IF(C4>69,"4",IF(C4>59,"3",IF(C4>49,"2","1"))))
	Concrete/CMU	=IF(C5>49,"1",IF(C5>39,"2",IF(C5>29,"3",IF(C5>19,"4","5"))))
	Steel	=IF(C6>49,"1",IF(C6>39,"2",IF(C6>29,"3",IF(C6>19,"4","5"))))
Public Housing	Percentage	=IF(C9>59,"5",IF(C9>49,"4",IF(C9>39,"3",IF(C9>29,"2","1"))))
General Growth Age	Average age	=IF(C10>100,"4",IF(C10>75,"3",IF(C10>60,"5",IF(C10>30,"2","1"))))

Table 5.1--continued

Indicator	Variable	Scoring Logic
Section 5: Policy and Incentives		
Recycling	Mandatory Recycling	=IF(C3="yes","5",IF(C3="no","1",""))
	Percentage	=IF(C4>49,"5",IF(C4>39,"4",IF(C4>29,"3",IF(C4>19, "2","1"))))
	C&D included	=IF(C5="yes","5","1")
Waste Reduction	Mandatory Waste Reduction	=IF(C6="yes","5","1")
	Percentage	=IF(C7>49,"5",IF(C7>39,"4",IF(C7>29,"3",IF(C7>19, "2","1"))))
Permits	Required Demolition Permit	=IF(C8="yes","5","1")
	Differentiation between demolition and deconstruction	=IF(C9="yes","5","1")
Incentives	Monetary	=IF(C10="yes","5","1")
	Permitting	=IF(C11="yes","5","1")
	Waiting Period	=IF(C12="yes","5","1")
	Days	=IF(C13>64,"5",IF(C13>49,"4",IF(C13>34,"3",IF(C13 >19,"2","1"))))
Section 6: Waste Quantities		
C&D Waste	Total waste produced annually	=IF(E3>15,"5",IF(E3>10,"4",IF(E3>5,"3",IF(E3>2,"2" ,"1"))))
	Total C&D waste produced annually	=IF(E4>38%,"5",IF(E4>30%,"4",IF(E4>22%,"3",IF(E 4>14%,"2","1"))))
	Residential demolition permits	=IF(E5>25%,"5",IF(E5>20%,"4",IF(E5>15%,"3",IF(E 5>10%,"2","1"))))
Landfill	Number of C&D landfills	=IF(C7>4,"1",IF(C7>3,"2",IF(C7>2,"3",IF(C7>1,"4"," 5"))))
	Expected life of C&D landfills	=IF(C8>40,"1",IF(C8>30,"2",IF(C8>20,"3",IF(C8>10, "4","5"))))
	Landfill tipping fees	=IF(C9>60,"5",IF(C9>50,"4",IF(C9>40,"3",IF(C9>30, "2","1"))))

Scoring User Input – Section 1

Regional Economics

Unemployment rate is a variable used as an indicator of economic health. As the unemployment rate increases, the economic health of the region is impacted. For this reason, the lower the unemployment rate, the higher the score received for this variable.

The unemployment rate varies usually in the single digit percentages. For this reason, if the unemployment rate is less than 3% the user receives a score of 5, if the rate falls from 3% to 4% the score is 4, from 4% to 5% the score is 3, from 5% to 6% the score is 2, and any rate above 6% receives a score of 1.

Regional Growth

The population growth rate is a variable used as an indicator of the regional growth. As the rate of growth of the population increases demand increases for infrastructure, homes, schools, and land resulting in an increase in C&D waste. Regions experiencing growth would be more likely to succeed in implementing a new waste reduction strategy than, for example, a rural county experiencing a negative growth rate. Therefore, as the growth rate increases the score for the variable increases.

Cost of Living

The average income per household is a variable used as an indicator of the salaries and cost of living within the region. Deconstruction requires a level of accessible disposable cash – cash available for non-necessity items. As income increases, the quantity of disposable cash usually increases as does the likelihood of successful implementation increases.

Scoring User Input – Section 2

Existing Development

Four levels of existing development were provided to the user: large metropolitan, small metropolitan, nonurban, and rural. Developed metropolitan areas have several advantages for implementing the deconstruction process. As land becomes scarce, land value increases, redevelopment occurs, and infrastructure is established. All of these factors assist in implementing deconstruction therefore a large metropolitan region receives a higher score than small metropolitan regions. Small metropolitan regions may contain some of the support infrastructure and programs needed to support the deconstruction process while non urban areas may not. As the level of existing development decreases, the score for the variable decreases with a rural region receiving the lowest score for the category.

Current Development

The current development is broken into two categories, infill and sprawl. The sum of the percentage of infill and sprawl must equal 100%. If the user enters values that do not sum to 100 the assessment tool prompts the user accordingly as seen in Figure 5.6. As the amount of infill increases, redevelopment and renovation are needed to update existing structures to support new growth. Therefore as the percentage of infill increases the user score for the variable increases. Sprawl development consists of developing virgin land, a process that does not require redevelopment, therefore as the percentage of sprawl increases the user score decreases.

Scoring User Input – Section 3

Recycling Businesses

The scoring for the recycling businesses was based on the data collected from the case studies and test area deconstructions. The weighted score for each type of recycling business was based on the average volume percent composition of each material. The benefit to the region by diverting waste is preserving landfill space. Landfill capacity is measured in volume; therefore, the volume percentages were used to weigh the scores of the recycling businesses. Table 5.2 shows all of the residential case studies used to calculate the weight and volume percentages of wood, metal, and concrete, and the average weight and volume percentage.

Table 5.2 Case study percent composition of wood, metal and concrete

Case Study	Wood		Metal		Concrete/Brick	
	Weight	Volume	Weight	Volume	Weight	Volume
Riverdale	9.60%	27.40%	1.80%	4.80%	52.30%	34.80%
Whole House	39.60%	20.00%	2.00%	na	35.40%	25.00%
by dEsign	1.50%	31.78%	2.00%	0.20%	77.00%	34.90%
14	55.70%	55.20%	11.20%	14.20%	18.70%	2.60%
2930	43.00%	39.40%	1.50%	5.7%	52.80%	42.80%
711	62.50%	80.80%	5.2%	10.4%	21.20%	4.00%
Germany	13.40%	na	0.20%	na	78.82%	na
Average	32.19%	42.43%	3.41%	7.06%	48.03%	24.02%

The score for each material is a result of multiplying the average composition percentage by the number of businesses accepting the material available in the region to recycle the product. This gives a higher score to the businesses that recycle the highest volume of recovered materials. The score for this variable also increases as the number of stores within the region increases.

Reuse Businesses

Reuse businesses available vary significantly from region to region. These businesses may be for profit or non profit organizations, they may purchases reclaimed materials or accept donations.

Salvaged material stores. These stores were assumed to accept more materials than both the recycling alternatives and the donation type organizations. Salvaged materials stores can accept all material types in addition to reclaimed items such as windows and doors not accepted at specific recycling businesses. The percentage used as a multiplier is a result of the average amount of diverted materials from the case studies and test area deconstructions.

Donation Centers. Centers such as Habitat for Humanity, Goodwill Industries and St. Vincent DePaul accept materials for resale or for use in their charitable functions.

These centers do not have the capability to recycle and act more as a transient location for reclaimed materials. The users DIPS score is increased if donation centers are available within the region.

Used Building Material Associations. These associations often act as a trading or "posting ground" for building materials. The "posting ground" works for those looking to sell or donate materials as well as those seeking materials. These postings must be updated frequently as materials are traded. Regions with access to such a posting ground can benefit from quick materials exchanges, however the expense of monitoring and updating the materials may act as a detriment if not funded by a government agency.

Manufacturing Businesses. Some manufacturing businesses may accept C&D debris as part of their manufacturing process or as a component in their final product such as custom cabinetry craftsmen. Identifying these businesses may require some additional effort but will assist the waste diversion effort.

Potential Deconstructors

Although almost anyone can be a potential deconstructor, this section is used to identify the number of existing businesses that may easily adapt their practices to accommodate deconstruction.

Salvage Companies: Salvage companies often have established clientele that accept reclaimed materials providing an alternative to landfilling. As the number of salvage companies increase, the potential for diversion increases.

Demolition Contractors: Demolition contractors perform salvage to some extent on approximately 40% of their projects (Jefferson Recycled Woodworks, 1997). They are familiar with the mechanics involved in removing structures, which is an asset in the deconstruction business.

Scoring User Input – Section 4

Residential

The three main residential construction types are wood, concrete or CMU, and steel. The primary intent of the deconstruction process is to divert materials from the waste stream and maintain their highest economic value. Diversion may occur in many ways, but to maintain the highest economic value the material should be directly reused versus recycled or downcycled. From case studies, a high percentage of the reclaimed components from wood frame may be directly reused. For this reason wood frame homes are more desirable than concrete or steel when reuse is the top priority. Although similar amounts of materials may be diverted for all structure types, more materials from steel and concrete homes are recycled versus reused. The user enters the percentage of each construction type represented in their region. The combined total for the residential structure types must equal 100 or the user is prompted to adjust their answers.

Public Housing

Public housing may act as a staging ground for trial deconstruction projects due to the HOPE VI program and government grants. Since 1993, the US Department of Housing and Urban Development's (HUD) HOPE VI program has disbursed approximately $500 million per year to local housing authorities for demolition, construction, or rehabilitation of public housing, as well as for planning and technical assistance. In FY 1998, the Hope VI budget included $550 million, of which $26 million was allocated for demolition and for revitalization of public housing designed to meet the special need and physical requirements of the elderly. A secondary goal of HOPE VI is to move public housing residents from the welfare rolls to living-wage employment. In addition, HUD's Section 3 requirements promote job creation and business development for public housing residents(US Department of Housing). For this reason, public housing increases the DIPS.

General Growth Age

The general growth age of the structures in a region can significantly impact the deconstruction process. Reviewing population growth rates for the past 100 years can indicate when an increase in growth occurred. In looking at the Florida population, there are two distinctive regimes of growth. The rate of growth for the State changed significantly in the mid 1950's (note the two distinctive line slopes) in Figure 5.12. Florida Population 1900 through present shows these two growth rates, one for pre-1950 and a second for post 1950. The growth rate in the 1930's and 1940's was between 2.6 and 3.7 percent. The growth rate for Florida in the 1950's was approximately 6 percent.

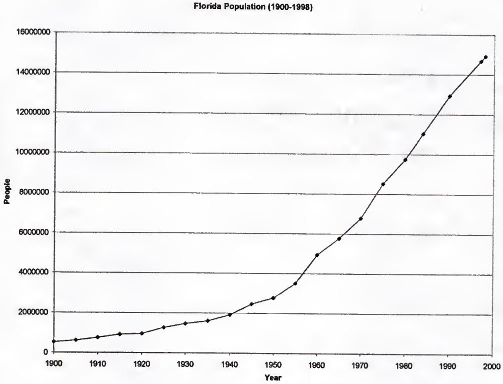


Figure 5.12 Population Versus Year (U.S. Bureau of Census)

The majority of the growth began post WWII, giving Florida an overall average growth age or around 55 years.

As the age of the structure increases two things occur. One is the structures materials may become more desirable from a material quality and historical standpoint, and two there is an increasing likelihood of damage or deterioration to the structure from the elements. Homes over 100 years of age may contain materials unavailable in the market today making deconstruction desirable, however historical societies may not allow for the structure removal. Structures built after World War II tend to lack the high value materials that can make deconstruction a profitable enterprise to contractors. Structures built prior to WWII are considered good candidates for deconstruction (Kibert and Languell, 2000). Although age is a factor deconstruction can divert waste on any building.

Scoring User Input – Section 5

Recycling

One of the first steps regions take to begin improving their waste management programs is to establish curbside recycling programs. Regions with established or required recycling programs have the beginning infrastructure and policy needed to pursue more aggressive programs. Mandating recycling, even though C&D materials may currently not be targeted, open the door for the additional recycling programs. For this reason, regions with established recycling programs receive a higher score than regions lacking an established recycling program.

Many states have established mandatory recycling percentage. As the mandatory recycling percentage increases, larger quantities of materials are diverted from landfills. As the mandatory recycling percentage is increased, regions must aggressively pursue new recycling programs or increase the types of materials recycled to achieve the required diversion rate. For this reason, as a regions mandatory recycling percentage increases, their score for the variable increases.

Waste Reduction

Often the term waste reduction and recycling are used interchangeably and therefore are often confused. Waste reduction requires that the waste generated is reduced, not that the current waste being produced is handled in a more environmentally sound manner. Waste reduction goals require additional planning and programs to achieve success. Remembering from the waste management hierarchy, reducing is a more sustainable option than recycling. Again as the mandatory waste reduction goal or percentage is increased, new and innovative methods must by incorporated to achieve regional goals. Requiring waste reduction increases the score received for this variable.

Permits

Requiring demolition permits indicates an active governmental role in regional planning. Requiring demolition permits allows the region to track the number of square feet demolished each year. The permitting process also allows the regulatory agency to monitor and inform permit recipients of new programs or incentives. If regions require permits differentiating between demolition and deconstruction it shows an innovative and environmentally conscious region and therefore receives a higher score.

Incentives

Regions providing incentives such as money and permitting preferences promoting deconstruction or other environmentally sound techniques will receive a higher DIPS.

Scoring User Input – Section 6

C&D Waste

All of the user input required in this section may not be available in all regions. Unfortunately there is no unified or mandated system for collecting solid waste data. The current record keeping practices make it statistically impossible to select a single variable to quantify the C&D waste stream in all regions. For this reason, three different variables are used to acquire data on the C&D waste stream. The first variable is the total quantity of waste (including MSW), the second variable is the quantity of C&D waste (in tons), and the third variable is the total number of square feet permitted for demolition. Of these three variables, regions are most likely to have the total waste stream (including MSW) data. For this reason, this variable was chosen to supports the Potential Diversion Quantity calculation.

Total waste produced annually. This value contains both C&D and MSW waste quantities. This value is used to calculate the Potential Diversion Quantity. There is no "score" resulting from this input that is included in the DIPS or DIPR calculation. The cell G3 in Section 6 is allocated to a logic statement that calculate a ratio of the number of alternative material outlets from Section 3 (=SUM('3'!C4+'3'!C5+'3'!C6+'3'!C9+'3'!G10+'3'!G11+'3'!G13)) and the number of landfills from Section 6 ('6'!C7). As the number of alternative outlets increases and the number of landfills decreases, the ratio increases. The higher the ration the higher the associated score that appears in the score cell in the row containing the total waste quantity variable. This calculation was entered in this cell so that all of the sections of the assessment tool were visually uniform

Total C&D waste produced annually. As stated previously this data may not be available in all regions therefore, the equations in the assessment tool are not directly dependent on this information. Although no calculations are directly related to the user input for this variable, if the input is provided, regionally appropriate output will result when the user reviews the comments section of the assessment tool. If this data is not entered it does not negatively affect the DIPS. If the data is entered, the amount of C&D waste will be compared to the total waste stream to provide a score. The greater the percentage of C&D waste the higher the score. The higher the percentage of C&D waste in the total waste stream the more likely the waste stream can be targeted for reduction.

Residential demolition permits. Again, since this information may not be available it therefore does not directly affect the calculators built into the assessment tool or the DIPS. If the information is provided, the total tonnage of residential demolition waste is calculated based on the average pounds of debris per square foot from Table 3.10. The calculated tonnage of residential demolition waste is then compared to the total C&D waste stream quantity (if entered by the user). The residential C&D waste component (percentage) of the total C&D waste is calculated. The greater the percentage of residential demolition waste compared to the total C&D waste stream the higher the variable score. The larger the waste stream, the more likely deconstruction can be used to divert waste from the landfills therefore increasing the DIPS.

Landfills

Number of C&D landfills. As the number of C&D landfills or facilities that accept C&D debris for disposal decrease, the variable score increases. As this fast and inexpensive disposal option decreases in availability, the more likely alternative programs or disposal options become necessary and accepted.

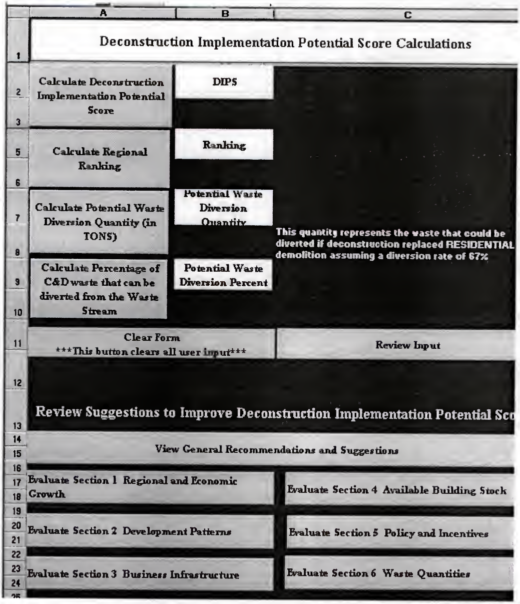
Expected life of C&D landfills. As the expected life of the existing C&D landfills decreases, the greater the pressure placed on the solid waste management team to continue providing low cost disposal options. The DIPS increases as the expected life of the C&D landfills decrease.

Landfill tipping fees. As landfill tipping fees increase, contractors and those in need of waste disposal are more likely to look to alternative less expensive disposal options (Kincaid et al., 1995). This variable score increases as the tipping fees increase.

Output Scores: Assessment Tool Worksheet 8-Calculations

The calculations worksheet allows the user to calculate four indicators: 1) the Deconstruction Implementation Potential Score (DIPS), 2) the Deconstruction Implementation Potential Ranking, 3) the Potential Waste Diversion Quantity, and 4) the Potential Waste Diversion Percentage. The user may also review or clear the input for the assessment tool. The calculations page is shown in Figure 5.13.

Although this section only contains one worksheet, the calculations require use of worksheets 2 through 7 using both user input and the variable scores that result from the logic statements. In addition to the calculations this worksheet provides the user with the opportunity to review general and regionally specific comments.



Deconstruction Implementation Potential Score Calculations

This quantity represents the waste that could be diverted if deconstruction replaced RESIDENTIAL demolition assuming a diversion rate of 67%

A
B
C
1
2
3
5
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7
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10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
Calculate Deconstruction Implementation Potential Score
DIPS
Calculate Regional Ranking
Ranking
Calculate Potential Waste Diversion Quantity (in TONS)
Potential Waste Diversion Quantity
Calculate Percentage of C&D waste that can be diverted from the Waste Stream
Potential Waste Diversion Percent
Clear Form
This button clears all user input
Review Input
Review Suggestions to Improve Deconstruction Implementation Potential Sc
View General Recommendations and Suggestions
Evaluate Section 1 Regional and Economic Growth
Evaluate Section 4 Available Building Stock
Evaluate Section 2 Development Patterns
Evaluate Section 5 Policy and Incentives
Evaluate Section 3 Business Infrastructure
Evaluate Section 6 Waste Quantities

Figure 5.13 Assessment Tool Calculations

Deconstruction Implementation Potential Score

The basic progress to determine the DIPS includes summing the scores for each variable. This sum only provides the user with the total points their region received. The Ranking – the next calculation-is a more informative number for the user. The DIPS was included for future expansion of the assessment tool. As new variables are added to account for the commercial and industrial sectors the total attainable points will increase.

Once the maximum attainable points are established, the DIPS will be used to evaluate the region versus the ranking calculation.

Regional Ranking

The regional ranking calculator was added to normalize the DIPS to a scale out of 100. The sum of the users scores is divided by the total possible score to provide a score out of 100%. Based on the regions ranking the user will view one of five comments. The comments are selected based on the following logic statement: =IF(B6>84%,Comments!A5,IF(B6>69%,Comments!A6,IF(B6>54%,Comments!A7,IF(B6>39%,Comments!A8,IF(B6>1%, Comments!A9,""))))). The scores and comments are provided in Table 5.3.

Table 5.3 Ranking Scores and Comments

Ranking	Comment
>84%,	This region is an ideal candidate for deconstruction
69%-83%	This regions has many key factors that would contribute to a successful implementation of deconstruction
54%-68%	This region has a great base infrastructure needed to begin the implementation process
39%-53%	This region lacks several key factors that would assist in the successful implementation of deconstruction
<39%	This region lacks many of the factors that contribute to the success of the deconstruction process

These comments are only provided to the user as clarification of the ranking. Comments intended to assist the user are available via “clickable buttons” further down the calculations page as seen in Figure 5.13.

Potential Waste Diversion Quantity

The potential waste diversion quantity is calculated based on the total annual waste stream. The residential portion of this waste stream is isolated using the percentages identified in the Franklin Associates report. Once the residential portion of the waste stream is isolated, the average case study diversion rate of 67% as calculated from the case study and test deconstruction data is used to determine the potential waste diversion quantity.

Potential Waste Diversion Percentage

The diversion percentage is calculated using the potential diversion quantity (calculated previously) and dividing it by the annual C&D waste stream. This calculation is dependent on the user entering the total annual C&D waste stream in Section 6 and therefore will only be available to user that have entered the C&D waste stream variable.

Output Comments: Worksheets 9 through 15-Comments

The output section of the assessment tool provides the most important information to the user. These sections were designed to educate the user about deconstruction and to provide suggestions, comments, and recommendations to the user to improve the regions potential to successfully implement deconstruction as a waste reduction strategy. The general comments are intended to provide the user with basic information regarding the variables and implementing a successful deconstruction process. The regionally specific comments review the scores achieved based on the user input for each variable. The comments the user will see are dependent on the score the variables received. These comments are intended to provide the user with guidance to improve or alter the factors that influence successfully implementing deconstruction. Logic statements are also used to determine the comments provided to the user. For example, the logic statement assigning comments to the Unemployment rate variable is =IF(C2>"3",Comments!A17,IF(C2>"0.1",Comments!A16,"")). Table 5.4 contains the logic statement used to determine the assessment tool comments.

Table 5.4 Output Comments Logic Statements

Indicator	**Variable**	**Comment Logic**
Section 1: Regional and Economic Growth		
Regional Economics	Unemployment Rate	=IF(C2>"3",Comments!A17,IF(C2>"0.1",Comments!A16,""))
Regional Growth	Population Growth Rate	=IF(C3>"3",Comments!B17,IF(C3>0.01,Comments!B16,""))
Cost of Living	Average Income Per Household	=IF(C4>"3",Comments!C17,IF(C4>"0.1",Comments!C16,""))
Section 2: Development Patterns		
Existing Development	1 = Large Metropolitan 2 = Small Metropolitan 3 = Nonurban 4 = Rural	=IF(C2=5,Comments!A20,IF(C2=4,Comments!A21,IF(C2=2,Comments!A22,IF(C2=1,Comments!A23,""))))
Current Development	Infill	=IF(C3>3,Comments!B21,IF(C3>=1,Comments!B20,""))
	Sprawl	=IF(C4>"3",Comments!C20,IF(C4>"0.1",Comments!C21,""))
Section 3: Business Infrastructure		
Recycling Businesses	Wood	=IF(C3>=0.3794,Comments!A27,IF(C3<0.3794,Comments!A26,""))
	Metal	=IF(C4>=0.1402,Comments!B27,IF(C4<0.1402,Comments!B26,""))
	Concrete/Brick	=IF(C5>=0.4802,Comments!C27,IF(C5<0.4802,Comments!C26,""))
Reuse Businesses	Salvaged Materials Stores	=IF(C6=1,Comments!D26,IF(C6=0,Comments!D27,""))
	Habitat for Humanity	=IF(C7=1,Comments!E27,IF(C7=0,Comments!E26))
	Used Building Materials Associations	=IF(C8=1,Comments!F26,IF(C8=0,Comments!F27))
	Manufacturing Businesses	=IF(C9=1,Comments!G26,IF(C9=0,Comments!G27))
Potential Deconstructors	Salvage Companies	=IF(C10=1,Comments!H26,IF(C10=0,Comments!H27))
	Demolition Contractors	=IF(C11>=1,Comments!I26,IF(C11=0,Comments!I27))
Section 4: Available Building Stock		
Residential	Wood	=IF(C3>3,Comments!A31,IF(C3>=1,Comments!A32,""))
	Concrete/CMU	=IF(C4>3,Comments!B31,IF(C4>=1,Comments!B32,""))
	Steel	=IF(C5>3,Comments!C31,IF(C5>=1,Comments!C32,""))
Public Housing	Percentage	=IF(C6>3,Comments!D31,IF(C6>=1,Comments!D32,""))
General Growth Age	Average age	=IF(C7>3,Comments!E31,IF(C7>=1,Comments!E32,""))

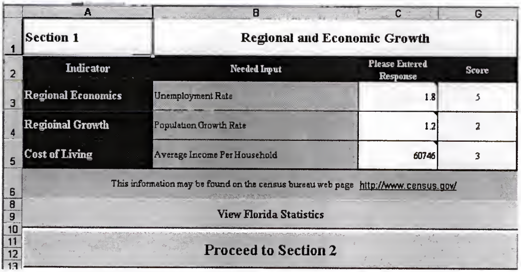
Table 5.4--continued

Indicator	Variable	Comment Logic
Section 5: Policy and Incentives		
Recycling	Mandatory Recycling	=IF(C3="5",Comments!A36,IF(C3="1",Comments!A37,""))
	Percentage	=IF(C4>0,Comments!B36,"")
	C&D included	=IF(C5>0,Comments!C36,"")
Waste Reduction	Mandatory Waste Reduction	=IF(C6="5",Comments!D36,IF(C6="1",Comments!D37,""))
	Percentage	=IF(C7>0,Comments!E36,"")
Permits	Required Demolition Permit	=IF(C8="5",Comments!F36,IF(C8="1",Comments!F37,""))
	Differentiation between demolition and deconstruction	=IF(C9="5",Comments!G36,IF(C9="1",Comments!G37,""))
Incentives	Monetary	=IF(C10="5",Comments!H36,IF(C10="1",Comments!H37,""))
	Permitting	=IF(C11="5",Comments!I36,IF(C11="1",Comments!I37,""))
	Waiting Period	=IF(C12>3,Comments!J36,IF(C12>=0,Comments!J37,""))
Section 6: Waste Quantities		
C&D Waste	Total waste produced annually	=IF(C3>3,Comments!A41,IF(C3>=0,Comments!A42,""))
	Total C&D waste produced annually	=IF(C4="1",Comments!B41,IF(C4="2",Comments!B42,IF(C4="3",Comments!B43,IF(C4="4",Comments!B44,IF(C4="5",Comments!B45,"")))))
	Residential demolition permits	=IF(C5="1",Comments!C41,IF(C5="2",Comments!C42,IF(C5="3",Comments!C43,IF(C5="4",Comments!C44,IF(C5="5",Comments!C45,"")))))
Landfill	Number of C&D landfills	=IF(C7>0,Comments!D41,"")
	Expected life of C&D landfills	=IF(C8>3,Comments!E41,"")
	Landfill tipping fees	=IF(C9>3,Comments!F41,IF(C9>=0,Comments!F42,""))

Assessment Tool Demonstration

To demonstrate the assessment tool, the needed information was collected on the Gainesville Florida area. The following figures show the assessment tool results after the programs calculating the scores have been run. The score column throughout the assessment tool remains blank until the user clicks on the "calculate" buttons. This was to avoid the users being influenced based on the score shown.

Figures 5.14 through 5.19 show sections 1 through 6 respectively. Figure 5.20 shows the top portion of the calculations page. (The bottom of the calculations page containing the "buttons" to evaluate each section and review comments has been eliminated). Figure 5.21 shows the general comments page and Figure 5.22 through 5.27 show the output section of the assessment tool containing comments for the user generated from scoring the variables. These comments are pulled from a database of comments on a hidden worksheet within the assessment tool.



Section 1 | **Regional and Economic Growth**

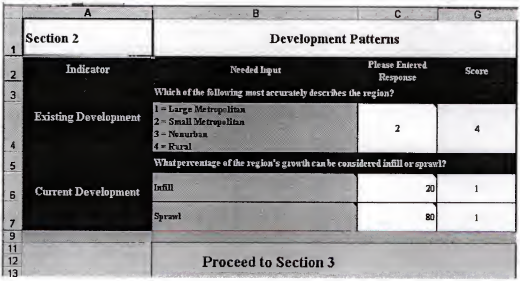
Indicator	Needed Input	Please Entered Response	Score
Regional Economics	Unemployment Rate	1.8	5
Regioinal Growth	Population Growth Rate	1.2	2
Cost of Living	Average Income Per Household	60746	3

This information may be found on the census bureau web page http://www.census.gov/

View Florida Statistics

Proceed to Section 2

Figure 5.14 Section 1 Assessment Tool Demonstration

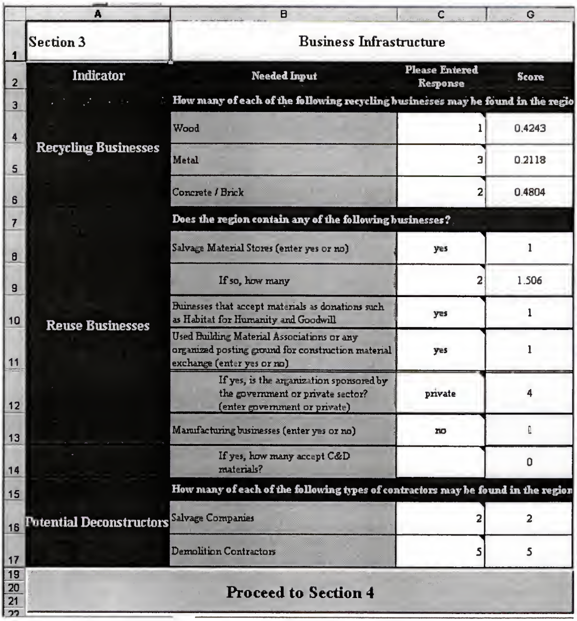


Section 2 | **Development Patterns**

Indicator	Needed Input	Please Entered Response	Score
	Which of the following most accurately describes the region?		
Existing Development	1 = Large Metropolitan 2 = Small Metropolitan 3 = Nonurban 4 = Rural	2	4
	What percentage of the region's growth can be considered infill or sprawl?		
Current Development	Infill	20	1
	Sprawl	80	1

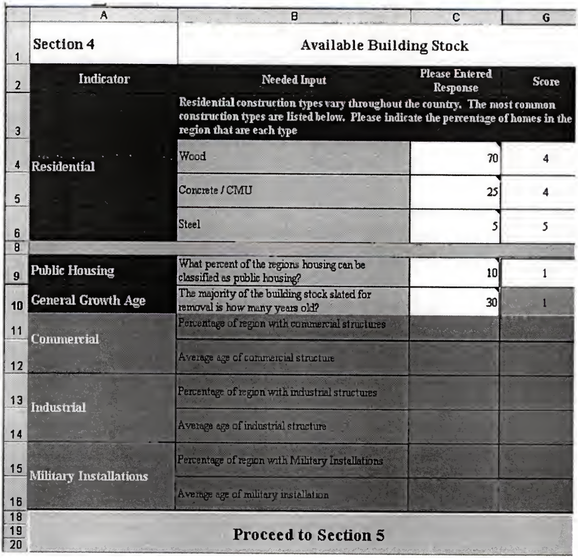
Proceed to Section 3

Figure 5.15 Section 2 Assessment Tool Demonstration



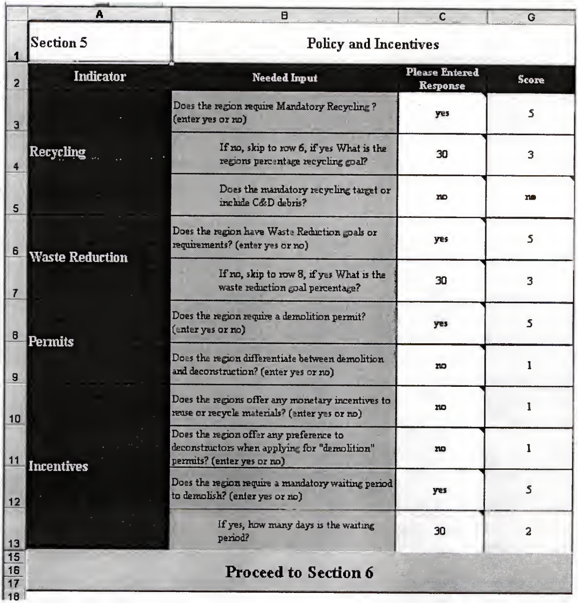
	A	B	C	G
1	Section 3	Business Infrastructure		
2	Indicator	Needed Input	Please Entered Response	Score
3		How many of each of the following recycling businesses may be found in the regio		
4	Recycling Businesses	Wood	1	0.4243
5		Metal	3	0.2118
6		Concrete / Brick	2	0.4804
7	Reuse Businesses	Does the region contain any of the following businesses?		
8		Salvage Material Stores (enter yes or no)	yes	1
9		If so, how many	2	1.506
10		Buinesses that accept materials as donations such as Habitat for Humanity and Goodwill	yes	1
11		Used Building Material Associations or any organized posting ground for construction material exchange (enter yes or no)	yes	1
12		If yes, is the arganization sponsored by the government or private sector? (enter government or private)	private	4
13		Manufacturing businesses (enter yes or no)	no	0
14		If yes, how many accept C&D materials?		0
15	Potential Deconstructors	How many of each of the following types of contractors may be found in the region		
16		Salvage Companies	2	2
17		Demolition Contractors	5	5
19 20 21 22	Proceed to Section 4			

Figure 5.16 Section 3 Assessment Tool Demonstration



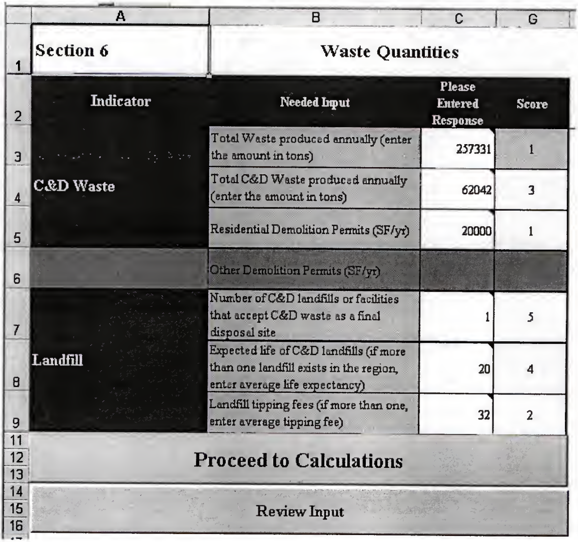
	A	B	C	G
1	**Section 4**	**Available Building Stock**		
2	**Indicator**	**Needed Input**	**Please Entered Response**	**Score**
3		**Residential construction types vary throughout the country. The most common construction types are listed below. Please indicate the percentage of homes in the region that are each type**		
4	**Residential**	Wood	70	4
5		Concrete / CMU	25	4
6		Steel	5	5
8				
9	**Public Housing**	What percent of the regions housing can be classified as public housing?	10	1
10	**General Growth Age**	The majority of the building stock slated for removal is how many years old?	30	1
11	**Commercial**	Percentage of region with commercial structures		
12		Average age of commercial structure		
13	**Industrial**	Percentage of region with industrial structures		
14		Average age of industrial structure		
15	**Military Installations**	Percentage of region with Military Installations		
16		Average age of military installation		
18 19 20		**Proceed to Section 5**		

Figure 5.17 Section 4 Assessment Tool Demonstration



	A	B	C	G
1	Section 5	Policy and Incentives		
2	Indicator	Needed Input	Please Entered Response	Score
3	Recycling	Does the region require Mandatory Recycling ? (enter yes or no)	yes	5
4		If no, skip to row 6, if yes What is the regions percentage recycling goal?	30	3
5		Does the mandatory recycling target or include C&D debris?	no	no
6	Waste Reduction	Does the region have Waste Reduction goals or requirements? (enter yes or no)	yes	5
7		If no, skip to row 8, if yes What is the waste reduction goal percentage?	30	3
8	Permits	Does the region require a demolition permit? (enter yes or no)	yes	5
9		Does the region differentiate between demolition and deconstruction? (enter yes or no)	no	1
10	Incentives	Does the regions offer any monetary incentives to reuse or recycle materials? (enter yes or no)	no	1
11		Does the region offer any preference to deconstructors when applying for "demolition" permits? (enter yes or no)	no	1
12		Does the region require a mandatory waiting period to demolish? (enter yes or no)	yes	5
13		If yes, how many days is the waiting period?	30	2
15–18	Proceed to Section 6			

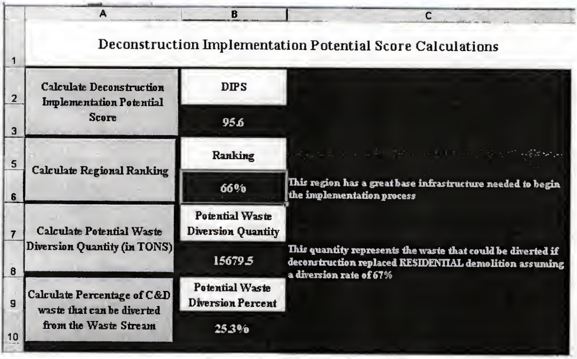
Figure 5.18 Section 5 Assessment Tool Demonstration



Section 6 — **Waste Quantities**

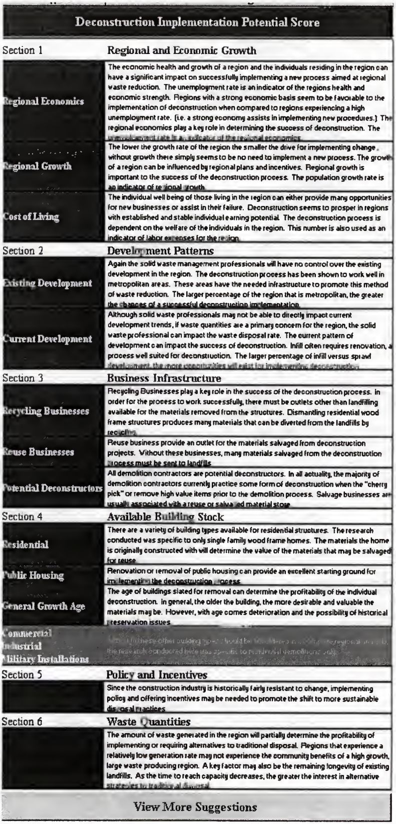
Indicator	Needed Input	Please Entered Response	Score
C&D Waste	Total Waste produced annually (enter the amount in tons)	257331	1
	Total C&D Waste produced annually (enter the amount in tons)	62042	3
	Residential Demolition Permits (SF/yr)	20000	1
	Other Demolition Permits (SF/yr)		
Landfill	Number of C&D landfills or facilities that accept C&D waste as a final disposal site	1	5
	Expected life of C&D landfills (if more than one landfill exists in the region, enter average life expectancy)	20	4
	Landfill tipping fees (if more than one, enter average tipping fee)	32	2

Figure 5.19 Section 6 Assessment Tool Demonstration



	A	B	C
1	Deconstruction Implementation Potential Score Calculations		
2	Calculate Deconstruction Implementation Potential Score	DIPS	
3		95.6	
5	Calculate Regional Ranking	Ranking	
6		66%	This region has a great base infrastructure needed to begin the implementation process
7	Calculate Potential Waste Diversion Quantity (in TONS)	Potential Waste Diversion Quantity	
8		15679.5	This quantity represents the waste that could be diverted if deconstruction replaced RESIDENTIAL demolition assuming a diversion rate of 67%
9	Calculate Percentage of C&D waste that can be diverted from the Waste Stream	Potential Waste Diversion Percent	
10		25.3%	

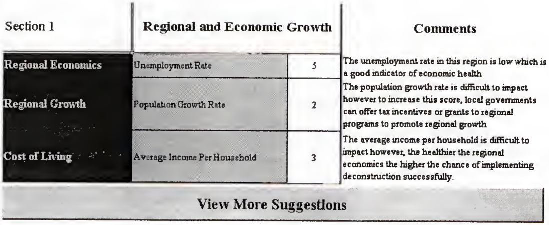
Figure 5.20 Calculations page of Assessment Tool Demonstration



Deconstruction Implementation Potential Score

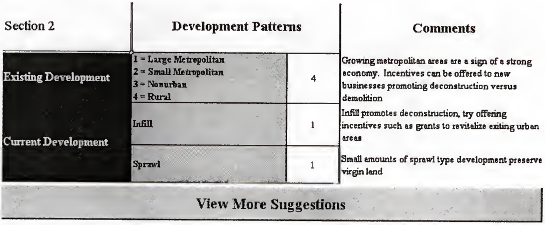
Section 1	**Regional and Economic Growth**
Regional Economics	The economic health and growth of a region and the individuals residing in the region can have a significant impact on successfully implementing a new process aimed at regional waste reduction. The unemployment rate is an indicator of the regions health and economic strength. Regions with a strong economic basis seem to be favorable to the implementation of deconstruction when compared to regions experiencing a high unemployment rate. (i.e. a strong economy assists in implementing new procedures.) The regional economics play a key role in determining the success of deconstruction. The unemployment rate is an indicator of the regional economics.
Regional Growth	The lower the growth rate of the region the smaller the drive for implementing change, without growth there simply seems to be no need to implement a new process. The growth of a region can be influenced by regional plans and incentives. Regional growth is important to the success of the deconstruction process. The population growth rate is an indicator of regional growth.
Cost of Living	The individual well being of those living in the region can either provide many opportunities for new businesses or assist in their failure. Deconstruction seems to prosper in regions with established and stable individual earning potential. The deconstruction process is dependent on the welfare of the individuals in the region. This number is also used as an indicator of labor expenses for the region.
Section 2	**Development Patterns**
Existing Development	Again the solid waste management professionals will have no control over the existing development in the region. The deconstruction process has been shown to work well in metropolitan areas. These areas have the needed infrastructure to promote this method of waste reduction. The larger percentage of the region that is metropolitan, the greater the chances of a successful deconstruction implementation.
Current Development	Although solid waste professionals may not be able to directly impact current development trends, if waste quantities are a primary concern for the region, the solid waste professional can impact the waste disposal rate. The current pattern of development can impact the success of deconstruction. Infill often requires renovation, a process well suited for deconstruction. The larger percentage of infill versus sprawl development, the more opportunities will exist for implementing deconstruction.
Section 3	**Business Infrastructure**
Recycling Businesses	Recycling Businesses play a key role in the success of the deconstruction process. In order for the process to work successfully, there must be outlets other than landfilling available for the materials removed from the structures. Dismantling residential wood frame structures produces many materials that can be diverted from the landfills by recycling.
Reuse Businesses	Reuse business provide an outlet for the materials salvaged from deconstruction projects. Without these businesses, many materials salvaged from the deconstruction process must be sent to landfills.
Potential Deconstructors	All demolition contractors are potential deconstructors. In all actuality, the majority of demolition contractors currently practice some form of deconstruction when the "cherry pick" or remove high value items prior to the demolition process. Salvage businesses are usually associated with a reuse or salvaged material store.
Section 4	**Available Building Stock**
Residential	There are a variety of building types available for residential structures. The research conducted was specific to only single family wood frame homes. The materials the home is originally constructed with will determine the value of the materials that may be salvaged for reuse.
Public Housing	Renovation or removal of public housing can provide an excellent starting ground for implementing the deconstruction process.
General Growth Age	The age of buildings slated for removal can determine the profitability of the individual deconstruction. In general, the older the building, the more desirable and valuable the materials may be. However, with age comes deterioration and the possibility of historical preservation issues.
Commercial **Industrial** **Military Installations**	[illegible]
Section 5	**Policy and Incentives**
	Since the construction industry is historically fairly resistant to change, implementing policy and offering incentives may be needed to promote the shift to more sustainable disposal practices.
Section 6	**Waste Quantities**
	The amount of waste generated in the region will partially determine the profitability of implementing or requiring alternatives to traditional disposal. Regions that experience a relatively low generation rate may not experience the community benefits of a high growth, large waste producing region. A key factor may also be the remaining longevity of existing landfills. As the time to reach capacity decreases, the greater the interest in alternative strategies to traditional disposal.

Figure 5.21 General comments section of Assessment Tool Demonstration



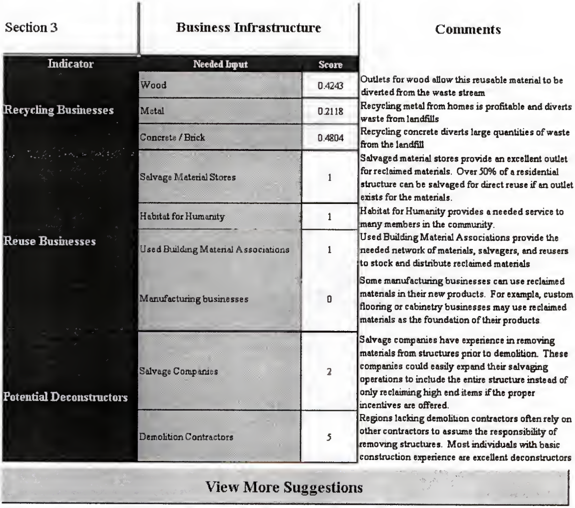
Section 1	Regional and Economic Growth		Comments
Regional Economics	Unemployment Rate	5	The unemployment rate in this region is low which is a good indicator of economic health
Regional Growth	Population Growth Rate	2	The population growth rate is difficult to impact however to increase this score, local governments can offer tax incentives or grants to regional programs to promote regional growth
Cost of Living	Average Income Per Household	3	The average income per household is difficult to impact however, the healthier the regional economics the higher the chance of implementing deconstruction successfully.

Figure 5.22 Section 1 demonstration comments



Section 2	Development Patterns		Comments
Existing Development	1 = Large Metropolitan 2 = Small Metropolitan 3 = Nonurban 4 = Rural	4	Growing metropolitan areas are a sign of a strong economy. Incentives can be offered to new businesses promoting deconstruction versus demolition
Current Development	Infill	1	Infill promotes deconstruction, try offering incentives such as grants to revitalize exiting urban areas
	Sprawl	1	Small amounts of sprawl type development preserve virgin land

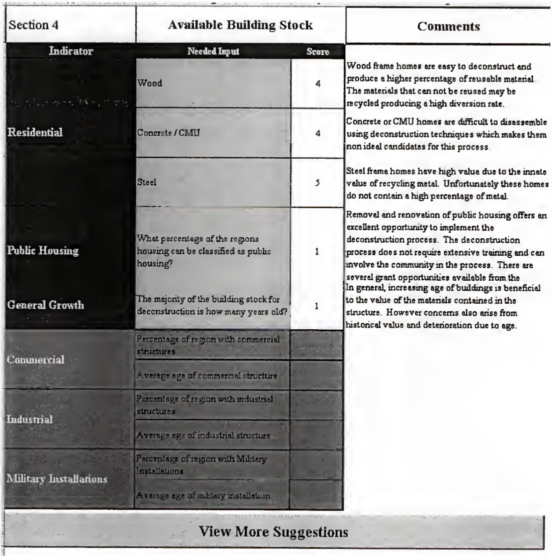
Figure 5.23 Section 2 demonstration comments



Section 3 | Business Infrastructure | Comments

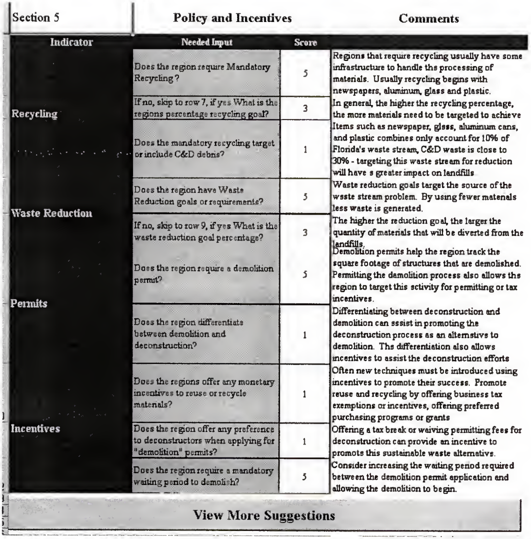
Indicator	Needed Input	Score	Comments
Recycling Businesses	Wood	0.4243	Outlets for wood allow this reusable material to be diverted from the waste stream
	Metal	0.2118	Recycling metal from homes is profitable and diverts waste from landfills
	Concrete / Brick	0.4804	Recycling concrete diverts large quantities of waste from the landfill
Reuse Businesses	Salvage Material Stores	1	Salvaged material stores provide an excellent outlet for reclaimed materials. Over 50% of a residential structure can be salvaged for direct reuse if an outlet exists for the materials.
	Habitat for Humanity	1	Habitat for Humanity provides a needed service to many members in the community.
	Used Building Material Associations	1	Used Building Material Associations provide the needed network of materials, salvagers, and reusers to stock and distribute reclaimed materials
	Manufacturing businesses	0	Some manufacturing businesses can use reclaimed materials in their new products. For example, custom flooring or cabinetry businesses may use reclaimed materials as the foundation of their products
Potential Deconstructors	Salvage Companies	2	Salvage companies have experience in removing materials from structures prior to demolition. These companies could easily expand their salvaging operations to include the entire structure instead of only reclaiming high end items if the proper incentives are offered.
	Demolition Contractors	5	Regions lacking demolition contractors often rely on other contractors to assume the responsibility of removing structures. Most individuals with basic construction experience are excellent deconstructors

Figure 5.24 Section 3 demonstration comments



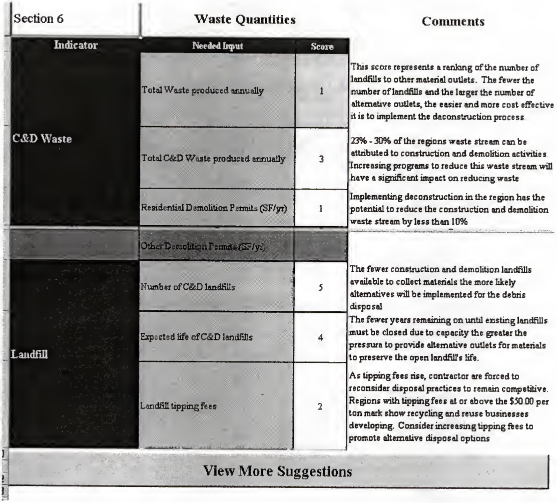
Section 4	Available Building Stock		Comments
Indicator	**Needed Input**	**Score**	
Residential	Wood	4	Wood frame homes are easy to deconstruct and produce a higher percentage of reusable material. The materials that can not be reused may be recycled producing a high diversion rate.
	Concrete / CMU	4	Concrete or CMU homes are difficult to disassemble using deconstruction techniques which makes them non ideal candidates for this process.
	Steel	5	Steel frame homes have high value due to the innate value of recycling metal. Unfortunately these homes do not contain a high percentage of metal.
Public Housing	What percentage of the regions housing can be classified as public housing?	1	Removal and renovation of public housing offers an excellent opportunity to implement the deconstruction process. The deconstruction process does not require extensive training and can involve the community in the process. There are several grant opportunities available from the
General Growth	The majority of the building stock for deconstruction is how many years old?	1	In general, increasing age of buildings is beneficial to the value of the materials contained in the structure. However concerns also arise from historical value and deterioration due to age.
Commercial	Percentage of region with commercial structures		
	Average age of commercial structure		
Industrial	Percentage of region with industrial structures		
	Average age of industrial structure		
Military Installations	Percentage of region with Military Installations		
	Average age of military installation		

Figure 5.25 Section 4 demonstration comments



Section 5	Policy and Incentives		Comments
Indicator	**Needed Input**	**Score**	
Recycling	Does the region require Mandatory Recycling ?	5	Regions that require recycling usually have some infrastructure to handle ths processing of materials. Usually recycling begins with newspapers, aluminum, glass and plastic.
	If no, skip to row 7, if yes What is the regions percentage recycling goal?	3	In general, the higher the recycling percentage, the more materials need to be targeted to achieve
	Does the mandatory recycling target or include C&D debris?	1	Items such as newspaper, glsss, aluminum cans, and plastic combines only account for 10% of Florida's waste stream, C&D waste is close to 30% - targeting this waste stream for reduction will have s greater impact on landfills
Waste Reduction	Does the region have Waste Reduction goals or requirements?	5	Waste reduction goals target the source of the wsste stream problem. By using fewer matenals less waste is generated.
	If no, skip to row 9, if yes What is the waste reduction goal percentage?	3	The higher the reduction goal, the larger the quantity of materials that will be diverted from the landfills.
Permits	Does the region require a demolition permit?	5	Demolition permits help the region track the square footage of structures that are demolished. Permitting the damolition process also allows ths region to target this sctivity for permitting or tax incentives.
	Does the region differentiate between demolition and deconstruction?	1	Differentiating between deconstruction and demolition can sssist in promoting the deconstruction process as an altemstivs to demolition. Ths differentiation also allows incentives to assist the deconstruction efforts
Incentives	Does the regions offer any monetary incentives to reuse or recycle materials?	1	Often new techniques must be introduced using incentives to promote their success. Promote reuse and recycling by offering business tax exemptions or incentives, offering preferred purchasing programs or grants
	Does the region offer any preference to deconstructors when applying for "demolition" permits?	1	Offering a tax break or waiving permitting fees for deconstruction can provide an incentive to promots this sustainable waste altemativs.
	Does the region require a mandatory waiting period to demolish?	5	Consider increasing the waiting penod required between the demolition permit application and allowing the demolition to begin.

Figure 5.26 Section 5 demonstration comments



Section 6 | Waste Quantities | Comments

Indicator	Needed Input	Score	Comments
C&D Waste	Total Waste produced annually	1	This score represents a ranking of the number of landfills to other material outlets. The fewer the number of landfills and the larger the number of alternative outlets, the easier and more cost effective it is to implement the daconstruction process
	Total C&D Waste produced annually	3	23% - 30% of the regions waste stream can be attributed to construction and demolition activities Increasing programs to reduce this waste stream will have a significant impact on reducing waste
	Residential Demolition Permits (SF/yr)	1	Implementing deconstruction in the region has the potential to reduce the construction and demolition waste stream by less than 10%
	Other Demolition Permits (SF/yr)		
Landfill	Number of C&D landfills	5	The fewer construction and demolition landfills available to collect materials the more likely alternatives will be implemented for the debris disposal
	Expected life of C&D landfills	4	The fewer years remaining on until existing landfills must be closed due to capacity the greater the pressura to provide alternative outlets for materials to preserve the open landfill's life.
	Landfill tipping fees	2	As tipping fees rise, contractor are forced to reconsider disposal practices to remain competitive. Regions with tipping fees at or above the $50.00 per ton mark show recycling and reuse businesses developing. Consider increasing tipping fees to promote alternative disposal options

Figure 5.27 Section 6 demonstration comments

Industry Contacts

There were three key contacts established for distribution and review of the assessment tool. The first contact was the Florida Center for Solid and Hazardous Waste Management. The FCSHWM serves the citizens of Florida by providing leadership in the field of waste management research and by supporting the Florida Department of Environmental Protection (FDEP) in its mission to preserve and protect the state's natural resources. A presentation was used to establish State level contacts for distribution of the assessment tool to the solid waste managers in the 67 Florida counties. The director of the FCSHWM, John Schert, suggested that the assessment tool be sent to the county recycling coordinators for review. Contacts at the FDEP were also provided a copy for review of the assessment tool.

The second contact was Pam Swingle at the EPA Region 4. This contact was established to pursue reviewers outside the State and to reach individuals employed in a regulatory environment. In addition to personally contacting industry professionals, the assessment tool was posted to the EPA website listserv. From this posting there were 19 requests to review the assessment tool.

The third key contact was Dr. Abdol Chini, Joint Coordinator of the International Council for Research and Innovation in Building Construction (CIB) Task Group 39 on Deconstruction. Dr. Chini played an integral role in establishing international contacts with deconstruction experts. The assessment tool was distributed to country representatives from the UK, Norway, Australia, Germany, Sweden, South Africa, New Zealand, the Netherlands, Portugal, and Japan

Testing the Prototype Assessment Tool

This assessment tool is a prototype. It is the first tool of its kind developed to evaluate a regions potential to successfully implement deconstruction as a waste reduction strategy. The most important information to be gained by the evaluation of this assessment tool is the usability and acceptability of a tool for use by individuals or governments to assist in managing the C&D waste stream. The scoring system for determining the implementation potential, at this stage, is experimental and will need to be further developed as statistically valid data becomes available.

The deconstruction process is not currently implemented successfully as a waste reduction strategy in enough regions to effectively test the tool for all variable scoring logic statements. For this reason, distributing the assessment tool for collection of regional DIPS would not be a statistically valid assessment. The important aspect of this tool, is, for the first time, the assembling, identifying, and evaluating regional factors to create a tool for solid waste managers to determine their deconstruction potential. The demonstration and distribution of the assessment tool was used to refine and validate this prototype as a tool to assist the waste management decision making process.

Categories of Reviewer

The assessment tool was distributed for review to four main categories of individuals. A complete list of individuals whom reviewed the tool may be found in Appendix B:

1. Deconstruction experts: The deconstruction expert category contained two groups of individuals. The first group was composed of individuals with hands on deconstruction experience and the second group was composed of individuals with research experience. This groups expertise was targeted to provide insight and comments on the appropriateness of variables selected for use in the analysis of data within the assessment tool to evaluate deconstruction potential within a region.
2. Recycling coordinators: In the State of Florida, the assessment tool was sent to all 67 county recycling coordinators or solid waste managers. This group is one of the potential end users of the assessment tool. Their comments regarding the availability of data needed as input, the applicability to their C&D waste status, and the overall usability of the assessment tool is necessary to ensure the tool meets the needs of the end user.

3. Government and regulatory agencies: Agencies that are not in direct contact with the handling of a regions solid waste but may influence the regulations or laws governing the processing of the waste. Although these agencies might not be the end user of the tool the agencies have the authority to require or mandate the implementation of sustainable waste management practices.
4. Private entities: Both businesses and individuals interested in implementing sustainable practices or starting deconstruction businesses. Input from these individuals will assist in determining the usability of the assessment tool as well as the tools ability to educate the user on the factor influencing the deconstruction practice.

Each group was targeted due to their unique ability to provide comments on several aspects of the assessment tool. Table 5.4 shows the reviewer categories and the desired input.

Table 5.4 Reviewers and Desired Input

	Variable Selection	Variable Presentation	Availability of needed information	Overall Usability	Applicability to managing C&D waste stream	Learning Device
Deconstruction Experts – Research	✓	✓		✓		✓
Deconstruction Experts – Physical	✓	✓		✓		✓
Solid Waste Managers		✓	✓	✓	✓	✓
Recycling Coordinators		✓	✓	✓	✓	✓
Government or Regulatory Agencies		✓	✓	✓	✓	✓
Private Organizations or individuals interested in sustainability		✓	✓	✓		✓

The questionnaire accompanying the assessment tool was dependent on the reviewer. The anticipated end users of the assessment tool are the solid waste managers or recycling coordinators. Reviewers in a solid waste decision making position received the survey found in Appendix C. The survey was geared toward the usability and individual regional results of the assessment tool. An additional request for comments was sent to the other reviewers. The request for comments included the following topics:

1. The Selection of Variables
2. Is the information requested for input available to most users?
3. Are there any key regional factors that have not been included?
4. Usability of the Assessment tool
5. Is the assessment tool overly complicated and if so, how should it be simplified?
6. What would increase the usability of the assessment tool?
7. Would this tool assist in determining if deconstruction could reduce the C&D waste stream in the region?

The goal of this research was to collect comments on the selection of variables, present information on those variable for review and validation, determine availability of needed information, assess overall usability, applicability and potential as a learning device. From the evaluations, these comments were solicited for possible enhancements to the assessment tool.

Assessment Tool Distribution Package

The assessment tool was distributed either by regular mail, e-mail, or presentations. The mailings of the assessment tool contained a cover letter, directions for viewing the presentation and running the assessment tool, the survey, and the CD. The CD contained a total of 5 files as listed below:

1. Assessment Tool (Excel Tool ready for user input)
2. Assessment Tool Demonstration (Excel Tool with data entered for the test area)
3. Assessment Tool Introduction (PowerPoint Presentation)
4. Assessment Tool Directions (Word file containing directions for running the presentation and the assessment tool)
5. Survey (Word file of the survey)

The cover letter, directions, and presentation are shown in Appendix D.

The size of the narrated and automated presentation file, even when compressed, was too large for may servers to handle. For this reason, e-mail was used for individuals that have a working knowledge of the deconstruction process and were proficient with Microsoft Excel.

Summary

The assessment tool was developed using Microsoft Excel. The tool was programmed in Visual Basic and is driven by macros. There are three main components of the assessment tool development: input, calculations and output. The assessment tool requires user input and is formatted with "clickable buttons" that prompt the user to proceed to the next section until the needed data has been entered. The user then has the option of proceeding to a calculations page. This page allows the user to calculate the regions DIPS, regional ranking, potential waste diversion quantity and potential waste diversion percentage. When the user "clicks" the calculate buttons, a series of logic statements evaluate the user input to produce scores for each variable. The scores and the user input are used to calculate the regions DIPS, regional ranking, potential waste diversion quantity and to provide regionally specific comments that the user may review to assist in increasing the regions DIPS. The prototype assessment tool was distributed to deconstruction experts, recycling coordinators, government or regulatory agencies and private entities for evaluation. The results of the evaluations may be found in Chapter 6.

CHAPTER 6
RESULTS AND DISCUSSION

Introduction

This chapter presents the results of the assessment tool distribution and review, end-user input and a discussion of the research findings. End-user input was obtained through questionnaires, interviews, presentations, phone conversations and e-mail surveys. The comments submitted by the assessment tool reviewers were grouped into five main categories. Each category of input is defined below.

1. Variable Selection or Clarification: This input indicated the appropriateness of the selection of variables used in the prototype assessment tool. Also included in this category is input identifying the need for additional definition or clarification of chosen variables.
2. Data Availability: User input addressing the availability of data required to complete the assessment tool.
3. Tool Expansion: End-user input regarding further development of the assessment tool to include additional structure types or descriptive components.
4. Usability and Editorial: End-user input regarding the mechanical usability of the tool as well as the structure of directions, hints, and comments. This category also includes editorial input.
5. Applicability: User input regarding the applicability to the management of solid waste and to solid waste managers.

An overview of the end-user input received is shown in Table 6.1. Each reviewer input category provided valuable insight into the usability of the assessment tool and its future development.

Table 6.1 End-User Input Categories.

Input Category Reviewer Category	Variable Selection or Clarification	Data Availability	Tool Expansion	Usability and Editorial	Applicability
Deconstruction Experts – Research	×	×	×	×	×
Deconstruction Experts – Physical	×	×	×		×
Solid Waste Managers	×	×		×	×
Recycling Coordinators	×	×		×	×
Government or Regulatory Agencies		×	×	×	×
Private Organizations or individuals interested in sustainability		×		×	×

A more detailed accounting of the input received from the supervised presentations and the unsupervised assessment tool distribution follows. This chapter also contains a discussion of the research findings from the prototype assessment tool distribution.

Supervised Presentations Results

FCSHWM

The presentation to the Florida Center for Solid and Hazardous Waste Management served to solicit input from a regulatory agency as well as identify regional contacts for the unsupervised distribution of the assessment tool. This presentation resulted in the following:

1. Revisions were made to the presentation that would accompany the general distribution of the assessment tool.

2. Establishing contacts with State level officials.
3. Determining regional level contacts (in this instance Florida's 67 county recycling coordinators).

The FCSHWM input to the presentation was incorporated prior to the tool's general distribution to the State and County contacts, international deconstruction experts, and the reviewers from the EPA Listserve posting. The three most important points from this demonstration session are summarized below followed by a detailed explanation.

1. The reduction of the C&D waste stream may not always be desired
2. The prediction of a low response rate from the counties
3. In general, involvement should begin at a State level with a "top down" process for instance starting with the FDEP

Reduction of C&D waste stream

Prior to revising the presentation for distribution the presentation contained a section that calculated the potential savings a county could expect from the waste stream diversion that results from implementing deconstruction, i.e. reducing the solid waste management expenses. Based on the total waste stream for the county, the average achievable diversion rate for deconstruction, and the cost per ton of processing C&D waste for the county, the diversion savings was calculated. The example used was Flagler County, Florida. This county was selected due to the availability of full cost accounting data on the true waste processing costs. Flagler county reported a cost of $10.09 per ton to process C&D waste (DH&C, 1999). Based on diversion calculations, it would be possible for the county to divert 12,125 tons of C&D waste resulting in a savings of $122,341 per year. It should be noted that Flagler County is one of Florida's smaller counties with a total population under 50,000.

John Schert at the FCSHWM noted that some counties' landfills are considered revenue generators and that reducing the waste stream may not be desired since it would reduce revenue generated to support other county programs. For this reason, the "potential cost savings to the county" portion of the presentation was removed as not to deter any county from participating in the assessment tool review. This issue of redirecting revenues is for future study.

Response Rate

The second main point examined the fact that there are simply no current factors motivating the county recycling coordinators or solid waste managers to participate in the survey. Most counties are somewhat offended if the inference is made that they are not doing the best possible job with managing their waste stream. The current attitude with respect to waste management is that the State will not run out of landfill space any time soon, therefore there is no incentive to alter current practices. Without some incentive or enforced regulations, the counties have little to motivate them to participate in waste stream reduction programs.

State Level Involvement

The third main point from the FCSHWM reaffirmed the need to distribute the assessment tool to agencies and individuals responsible for the regulations that govern the handling of C&D waste in addition to the intended end-users. The FCSHWM feedback indicated that the motivation to consider deconstruction appears to be driven by requirements generated by regulation and not from environmental or other altruistic concerns.

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The presentation with Dr. Chini consisted of an overview of the assessment tool and a section-by-section review of the selected variables. Dr. Chini felt that the assessment tool functioned well, and was satisfied with the selection of variables throughout this prototype tool. He proposed several future additions to the assessment tool, beyond the scope of this specific research study. The additions included, adding the commercial sector and possibly combining this assessment tool with another *structure-specific* deconstruction assessment tool, which focuses on determining the cost/benefit of building deconstruction for contractors.

City of Phoenix

The assessment tool was presented to the City of Phoenix, Solid Waste Management department in Arizona. Ronald J. Serio, P.E. Civil Engineer III; Joe Giudice, Landfill Superintendent; Michelle M. Woytenko, Solid Waste Superintendent; and Carl Smith, Administrative Assistant I (their recycling coordinator) attended the presentation. In general, the City of Phoenix is not actively pursuing waste reduction techniques nor do they have plans to alter current waste management practices. Although the city has a fairly high rate of growth, there is also an abundance of land available for waste disposal. Currently the tipping fees are approximately $20.00 per load at the C&D landfill. The main concerns within the government system are focused on energy, air pollution and water conservation.

Although the City of Phoenix was not actively pursuing waste reduction alternatives, their input regarding the usability of the assessment tool and the deconstruction concept are extremely important. The representatives from Phoenix had the following general comments that are summarized below:

- The City representatives felt that the required input data to perform the assessment was available or could be obtained by consulting different city departments.
- The waste management staff perceived they had a duty as city employees to provide low cost convenient waste disposal,
- They were concerned that the deconstruction process would place undo financial burden on the contractors – which may result in higher building cost and future political repercussions.
- They felt that increasing the tipping fees would result in increased illegal dumping

These comments indicate a high level of concern for the consumer and political aspects of waste management over the environmental impacts. The Phoenix data also reaffirmed the lack of interest at the regional level if there is no interest or mandate coming from the "top down". It should be noted that the State of Arizona currently has no existing recycling or waste reduction goals, thus further reinforcing the lack of long-term strategic initiatives directed by those in a position to influence implementation.

Unsupervised Assessment Tool Distribution Results

Response Rate

Regional and County

Of the 67 counties in Florida that were sent the assessment tool, only 5 counties returned completed surveys; Hardee, Duval, Hernando, Escambia and Taylor counties. Only two of the Florida Regional Planning Councils responded to the review request. Both regional planning councils stated that they do not have the resources/information to complete the survey.

State

Based on e-mail responses from the FDEP, the assessment tool was sent for review to several individuals within the solid waste management division. The FDEP has sent one response indicating, "they are currently busy preparing for a study and proposed legislation which could dramatically alter the State's recycling and waste reduction programs". A second e-mail followed from a reviewer with input regarding the assessment tool. In addition to editorial comments, the reviewer requested that the tool be forwarded to the individual Florida counties for their use.

International

Out of the 10 international contacts, Sweden, Australia, and the UK responded with input.

EPA and EPA Listserve

The EPA provided input through phone conversations. Of the 19 copies of the assessment tool that were distributed via e-mail to requests resulting from the EPA Listserve, there were 3 completed responses received.

Reviewer Input Results

The input received from the unsupervised assessment tool distributions were analyzed and grouped into the following categories.

1. Variable Selection and Clarification
2. Data Availability
3. Tool Expansion
4. Usability and Editorial
5. Applicability

The responses are presented below.

Variable Selection and Clarification

Comments in this category related to further defining the variables or clarifying needed user input. For example, several reviewers commented on the need to standardize measuring units associated with the waste quantity variable in Section 6 of the assessment tool. Comments such as "how is waste measured?" were reported from Sweden, METRO and the FDEP. The assessment tool originally did not state if the user was to enter the waste quantity in tons, pounds or cubic meters. A comment was added to this variable requesting the user inter the waste quantity in tons. Additional comments regarding Section 6 included:

- "is the assessment tool asking for the number of C&D landfills or the total number of facilities that accept C&D waste" (METRO)
- "If there is more than one landfill is the average tipping fee entered?" (Sweden, METRO, FDEP)
- "If there is more than one landfill is the average life or cumulative life of the landfills entered?" (Sweden, METRO, Duval County)

Each of these comments was addressed by incorporating additional text for clarification and directions into the prototype assessment tool.

There were similar comments for Section 3 of the assessment tool. In general, the users asked for further definition of the business types. For example, the assessment tool asks if the region contains a Habitat for Humanity. One user commented "not all Habitat for Humanity organizations accept materials donations – could the question be expanded to include all donation centers such as Goodwill" (METRO). The assessment tool was adjusted to accommodate this suggestion.

Data Availability

In general the reviewer input indicated that the information needed to complete the assessment tool was available. The solid waste managers indicated that if they did not have the information it was available from other departments within the government offices (Phoenix, FCSHWM, Duval County, METRO). There were two exceptions to this general comment that the needed data were available. The first exception was the input requiring "the annual quantity of C&D waste generated in the region", and the second exception was the input requiring "the number of square feet per year of residential demolition permits issued. As most evaluators commented, these data were not readily available. (Sweden, Australia, METRO, Regional Planning Councils, Hardee County, Phoenix) As indicated by METRO with respect to the annual quantity of C&D waste,

> "The total number for C&D debris may be hard to get for several reasons: Some municipalities may not even scale waste at the local C&D landfills which may charge by volume. C&D is likely to be coming into facilities that mix C&D with other municipal solid waste. METRO does waste sorts every two years to gather the data, but I would be surprised if others do this."

The Pacific Northwest is known for their environmental progressiveness. If this region does not have the data, as indicated, other regions probably would not. METRO also indicated difficulty with the question regarding the number of square feet per year of residential demolition permits.

> "Number of residential demolition permits is difficult to get…the reason is long and complicated, but the problem lies in the 27 cities that make up the METRO region and the different building code offices practices of coding and compiling demolition permit data. (Some do not even count demolition permits if they are part of large rehabilitation projects.)"

This problem is not isolated to the METRO region, other national and international reviewers commented these data were difficult to obtain because they are not regularly collected.

Tool Expansion

There were several comments requesting the assessment tool be expanded. The requests included the expansion of the tool to include multi-family residential structures and commercial structures. Additional expansion comments addressed the addition of a distance factor to be included in the landfill variable, recycling businesses, and reuse businesses. Sweden indicated that the distance to waste facilities or recycling businesses might affect the waste management decision.

Usability and Editorial

The editorial type input from the reviewers and any additional comments regarding the assessment tool usability were addressed and incorporated into the final version of the assessment tool.

Applicability

The input regarding the applicability of the assessment tool were fairly uniform in that the reviewers agreed the assessment tool could be a very effective device used for focusing and unifying an approach to handling C&D waste. The input also indicated that solid waste management personnel could use the assessment tool to assist in determining applicable waste management strategies. The FDEP commented that "… [the assessment tool] seems like a good tool. I hope some local programs can utilize it & hence do more deconstruction". The EPA was enthusiastic stating, "they felt the magnitude of the C&D waste stream was a primary concern and we are focusing on research efforts to reduce it [the C&D waste stream]". The EPA has previously and is currently funding deconstruction research. They felt that this assessment tool would compliment the structure specific assessment tool currently being developed under an EPA grant.

One of the main goals of developing the assessment tool was to provide solid waste managers with a systematic process to evaluate deconstruction that would assist in their decision making process. The assessment tool provides individuals responsible for managing the C&D waste stream a means to focus on the importance of accountability and to evaluate their regions potential to reduce the C&D waste stream by implementing deconstruction. Both deconstruction experts and solid waste managers at a regional level agree that the assessment tool fulfills its intended purpose of evaluating a regions' potential to successfully implement deconstruction as a waste reduction strategy. The UK response stated, "The assessment tool will play a functional role in deciding whether or not a region has the current capability to develop a deconstruction network, or what will be required to develop that market". Duval County, Florida stated, "Excellent tool, should prove to be very useful". The results indicate the development of a useful and usable assessment tool was accomplished. An issue for future research that must be addressed is that of promotion or mandating the use of such a tool.

Discussion

Response Rate

As anticipated by the FCSHWM, there were very few responses to the surveys from the county recycling coordinators and solid waste managers. Although these "working level" sources were an important part of the process, the FCSHWM had predicted there was little to motivate these individuals to evaluate the assessment tool and complete the survey. This was predicted because there were no forces driving the solid waste managers to investigate their current practices. Those that returned the survey responded positively to the concept of improving the solid waste management process. Another important issue regarding the management of C&D waste is the privatization of the disposal industry. Many counties are not actively responsible for the C&D waste due to the private ownership of many landfills. The solid waste managers that were interviewed supported this theory, which may also account for the lack of response to the survey.

Education

Interviews with solid waste managers and data from the returned surveys show that not all solid waste managers have knowledge of or access to the information on sustainable waste management alternatives. Even regions wishing to implement sustainable waste management practices may lack the access to the necessary input data needed to affectively pursue innovative and sustainable waste management techniques. Providing the individuals responsible for the management of solid waste the opportunity and means to improve their current waste management practices is vital to strategic planning necessary for establishing sustainable waste management alternatives.

Reviewers

The use and acceptance of the assessment tool was dependent on the regions pre established commitment to environmental issues and sustainability. Environmentally conscious individuals were not only more interested, but had the knowledge base to provide insightful input on the usability of the assessment tool. Individuals and regions without current involvement in sustainable practices were not motivated or interested in participating in the evaluation of the assessment tool.

The most thorough review was conducted by Bryce Jacobson, Associate Solid Waste Planner, Metro Regional Environmental Management, Portland Oregon. Bryce holds a position similar to that of members of the Florida Regional Planning Councils (FRPC). Both Metro and the FRPC authority span county jurisdictions to govern a broader region. The most important observation here was the overall enthusiasm and interest generated from Bryce, and the general disinterest from the State of Florida. It is believed that two factors significantly influenced this occurrence. First, the general societal attitude in the Pacific Northwest is more environmentally conscious and second, the regulatory environment in the Pacific Northwest promotes and requires the implementation of sustainable practices.

Input from the surveys and presentations indicated that many solid waste managers were not familiar with the magnitude of the national C&D waste stream nor is it an issue thought to be of concern. Due to regional data collection techniques, the type of data collected, and the privatization of the waste management industry, many solid waste managers and regulatory agencies were unaware of the exact quantity of C&D waste within their region. The general perception on the part of the regional solid waste managers was that they are already practicing appropriate waste management techniques or they perceived the magnitude of their C&D waste stream to be of little concern. In addition, many individuals were unaware of the deconstruction process and the impact it could have on the C&D waste stream. This again indicates the need for an educational outreach program.

Absence of Coordination in Solid Waste Management

There was an apparent lack of communication and collaboration between the upper level and lower level agencies. Upper level agencies being State and National waste management or environmental regulatory agencies and lower level referring to local/regional solid waste managers. The upper level agencies felt that the assessment tool should be distributed to lower level waste management for their use. For example, the FDEP recommended, “asking some counties to test the assessment tool”. The State was unaware that the counties had received and for the most part disregarded testing the assessment tool. The lower level waste management perceived they were doing the best possible job in managing their waste streams. The perception was that if they were not correctly managing their waste stream there would be some form of state intervention and, since there wasn’t, they must be doing a good job. The upper levels are under the impression that the lower levels are actively pursuing and continuously improving their waste management operations while in reality the lower levels are relying on upper level intervention.

The target users remain the individuals responsible for the management of the C&D waste stream. Results from this research show that the assessment tool provides the means to evaluate this sustainable waste management alternative and mandates or regulations can provide the needed incentives. The research revealed that individuals in upper level positions such as State or national waste management offices are too removed from the direct handling of the daily waste stream management activities to effectively use the assessment tool. These officials indicated that regional level officials should use the assessment tool, “Seems like a good tool, I hope some local programs can utilize it and hence do more deconstructions” (FDEP).

This tool would also prove useful for Regional Planning Councils or growth management departments. “This tool could be used by government planning groups to develop regional strategies" (Australia). The tool could assist in developing a regional growth strategy, which in turn can provide the solid waste managers with assistance in determining the proper disposal options to pursue. The void left by the lack of incentives or mandates remain a key factor in the lack of the tools use.

Implementing Deconstruction

Each individual and region will have different priorities relating to the environment. The movement toward sustainability is often time-consuming and gradual. There are many significant environmental benefits that can result from the implementation of the deconstruction process as shown in Table 2.5. Expanding the awareness of deconstruction and providing the tools to evaluate the effectiveness of the process are key factors in the acceptance and adoption of this sustainable process.

Currently there are only two instances where the deconstruction process can occur. First, the process can occur where strict waste management regulations exist mandating high percentages of reuse and recycling (a top down process) and second, where there is an individual drive to use the deconstruction process (a bottom up process). The bottom up process result in a small scale implementation and waste reduction efforts. Unfortunately, there are not enough concerned individuals to significantly affect the total C&D waste stream through this small scale approach. This research indicates that mandating or requiring the deconstruction process would be the most effective means to achieve large scale implementation. Therefore, of these two cases, the most viable way of implementing deconstruction as a waste reduction strategy is through mandating the process or, from the top down.

The mandating of sustainable C&D waste management practices is imperative due to the trend toward privatization of the waste disposal industry. The privatization of government agency operations is being aggressively pursued by many government controlled landfill operations. This trend is a business model that appears to be the way of the future. Unfortunately, this privatization leads to two problems. First, the construction industry – comprised mostly of midsize construction firms, operates under a tight profit margin (usually around 5% or less). As in most industries, the construction and demolition companies are not willing to jeopardize this profit margin by implementing reuse programs or expanding their demolition practices to deconstruct if the company will not realize an immediate and significant profit. Most businesses feel it is simply not worth the financial risk of a loss of competitiveness, and hence profit, to be environmentally friendly. Without mandates to alter current contractor and waste management activities there is no incentive for the private sector to reduce the C&D waste stream. Second, reducing the quantity of C&D waste that is sent to the landfills can reduce the profit made by the landfill owner. Landfills charge by the ton, or by the load of debris. Reducing these total quantities of waste would in turn reduce the revenue generated by the private owners of these facilities. Again, for the landfill owners, this is not desirable.

Positive cash flow is also an issue with government owned and operated landfill facilities. As stated previously, the revenue generated from waste disposal activities is often used to support other regional programs especially in regions lacking alternative revenue generators such as tourism or a large tax base. Reducing the quantity of C&D materials sent to these landfills could reduce the regions ability to support or fund their essential programs.

Summary

The assessment tool end-user input was obtained through questionnaires, interviews, presentations, phone conversations and e-mail surveys. Data was collected on variable selection and clarification, data availability, assessment tool expansion, usability and editorial issues, and the applicability to solid waste management. The results from the supervised presentations and the unsupervised distribution of the assessment tool are summarized below:

- The selection of variables for inclusion in the assessment tool was not disputed.
- Clarification and further definition of some of the assessment tool variables was requested and have been incorporated into the final version of the assessment tool.
- The end-user input indicates the data needed to complete the assessment tool is available with the exception of two variables, the C&D waste quantity and the number of square feet per year of residential demolition permits.
- There were several requests to expand the assessment tool to include multi-family and commercial structures and to combine the assessment tool with other structure specific deconstruction tools currently being developed.
- The input regarding usability and editorial comments were incorporated into the final version of the assessment tool.
- National, State and regional input indicate the assessment tool should be used by individuals responsible for the management of solid waste.

CHAPTER 7
CONCLUSION AND RECOMMENDATIONS

Introduction

This chapter identifies the original research objectives and discussed how each objective was achieved. The objectives are followed by conclusions and recommendations.

Research Objectives

The overall objective of this research project was to develop a prototype assessment tool that allows a user to evaluate a regions' potential to successfully implement deconstruction as a waste reduction strategy. The assessment tool was targeted at entities that are responsible for solid waste management and was intended to provide them with a means to analyze their region to determine if deconstruction could be an effective strategy to reduce the waste stream generated from single family residential demolitions and renovations. Although this tool was developed to specifically address the residential deconstruction process, an additional, and possibly more significant impact is that this tool can also be used in the solid waste management strategic planning process to produce an overall deconstruction strategy. The important contribution of this research effort is that for the first time, a tool that identifies, assembles, and evaluates regional factors allowing solid waste managers to determine their potential to successfully implement deconstruction is now available. The main project objective was broken into seven sub-objectives that are presented below.

Objective 1: Determine the (a) magnitude of the national C&D waste stream and (b) isolate the residential demolition and renovation quantities to (c) determine the potential waste reduction quantity that implementing deconstruction could have on the national waste stream.

Analyzing the domestic and international waste streams show that the United States has one of the largest C&D waste streams of any industrialized country. Over one third of this country's waste stream is generated by a single industry (the construction industry) indicating that the current C&D waste disposal process is not from sustainable. The C&D waste stream is composed of three main waste categories; demolition waste, renovation waste, and new construction waste. The residential demolition and renovation portions of the waste stream, when isolated, constituted a national annual quantity of 51.1 million tons. Based on this research, residential deconstruction case studies and the test area deconstructions show a calculated average achievable waste diversion rate of 67%. Implementing residential deconstruction could potentially reduce the residential demolition and renovation waste stream by 34.3 million tons. This reduction equates to 25.2% of the **total** annual construction industry waste stream. A thorough examination of these waste streams may be found in Chapter 2 while deconstruction diversion rate data is located in Chapter 3.

Objective 2: Deconstruct several wood frame single-family residential structures to validate existing case study deconstruction data and to add to the deconstruction data available for analysis.

A total of six single-family residential structures were deconstructed in the test area to provide data to fulfill objectives 3 and 4. The detailed findings from the deconstructions are located in Chapter 3.

Objective 3: Determine the types and quantities of materials that may be diverted from the waste stream by deconstructing wood frame single-family residential structures.

Domestic and international residential deconstruction case studies and the six test area deconstructions provided the data to identify the most common material components and their corresponding quantities that are generated by the residential deconstruction process. The case study and test area data is provided in detail in Chapter 3.

Objective 4: Identify variables and influence factors affecting the success and implementation of deconstruction.

The domestic and international case studies, the test area deconstructions, lessons learned from other C&D cases studies, and interviews with deconstruction researchers, deconstruction experts, and solid waste management officials, combined to identify the factors influencing and the variables that affect the implementation of deconstruction. The variables are identified and justified at the end of Chapter 3 and throughout Chapter 4.

Objective 5: Develop a prototype deconstruction implementation assessment tool by isolating and quantifying selected variables specific to regional deconstruction implementation.

Variables that are specific to the regional implementation of the deconstruction process were isolated from the contractor and structure specific variables to create the assessment tool. The assessment tool was developed in Microsoft Excel and is driven by macros as explained in Chapter 5.

Objective 6: Validate the prototype assessment tool through reviews by deconstruction experts, solid waste managers, and government or regulatory agencies.

The assessment tool was distributed to a total of 112 individuals and organizations. The reviewers included deconstruction experts, solid waste mangers, and government agencies. A total of 22 completed responses were returned. The input from the reviews is contained in Chapter 6.

Objective 7: Provide recommendations for implementing sustainable waste management practices such as deconstruction on a long-term basis.

Recommendations for the assessment tool end-users are contained within the assessment tool. The assessment tool has six sections that provide the user with regionally specific feedback to assist in improving the regions potential to successfully implement deconstruction. Recommendations based on this completed research study are also provided, at the end of this chapter.

Conclusion

State of the National C&D Waste Stream

Current State

The C&D portion of the national waste stream is 136 million tons per year or 34% of the total waste stream. The U.S. C&D waste stream is one of the largest waste streams of any industrialized country

Future State

National C&D waste stream data show the quantity of C&D waste will continue to increase. Data collected on the numbers of C&D landfills indicate the numbers of C&D landfills will continue to decrease.

Waste Impact if No Action is Taken

Increasing waste and decreasing disposal facilities will result in adisproportionately high increases in tipping fees, increased illegal dumping, and unnecessary environmental degradation.

Waste Management Professional's Knowledge of the C&D Waste Stream

National

National agencies such as the EPA have previously funded research projects to determine the magnitude of the C&D waste stream. As a result, national level waste management professionals are aware of and concerned by the magnitude of the national C&D waste stream.

State

State level waste management professionals feel that they have a working knowledge of the magnitude of the State C&D waste streams. This research showed, however, that the true magnitude of the C&D waste stream is actually not known due to the privatization of many landfill operations and the lack of enforcement related to the collection of accurate C&D waste data.

Regional

The regional waste management professional's knowledge of the C&D waste stream is dependent on the nature of landfill ownership, public or private, the size and sophistication of the waste management operation, and the data collection processes and capabilities within their region. Most regional and local governments are unaware of the total State or National C&D waste stream magnitude.

Planning for Future Impact of the C&D Waste Stream

National

Agencies such as the EPA are actively funding research efforts studying waste reduction alternatives. However, there is currently no strategic waste reduction plan or national requirements specifically targeting the implementation of the deconstruction process.

State

State involvement is highly dependent on specific State factors such as the magnitude of the waste stream, population density of the state, availability of landfills, and political climate. Based on the research findings the State agencies indicate that they encourage the implementation of waste reduction strategies and are at some level conducting fact finding studies as well as actively pursuing legislation toward improving the management of solid waste.

Regional

The disconnection and lack of collaboration in the waste management industry became apparent at the regional level. Most regions are not actively pursing waste reduction strategies due primarily to two factors. The first reason was the general lack of "top down" pressure to drive the waste reduction process even though the State level agencies believe the regions are actively pursuing waste reduction strategies. The second reason is the lack of access to and knowledge of sustainable waste management alternatives. The education and training needed could be provided through a strategic planning process.

Identifying C&D Waste Reduction Strategies

Referring back to the waste management hierarchy in Figure 2.5, there are three categories of C&D waste management that are more sustainable than landfilling, burning and composting. These are recycling, reusing and reducing.

Recycling

Increasing recycling operations will assist in reducing the amount of C&D materials that are landfilled, however, this process does not reduce the magnitude of the C&D generated. Fortunately recycling allows the diversion of some of the materials that would ordinarily be landfilled. Unfortunately, most recycling programs do not target materials contained in the C&D waste stream. Most existing recycling programs target materials such as newspaper, glass, and plastics. Although these recycling programs are an important step in improving the management of solid waste they do not address the current C&D waste stream concerns.

Reuse

The reuse option is moving the process further toward sustainable waste management by reducing the quantity of the materials sent to landfills. The reuse alternative can include reusing existing structures through renovation, or reusing building materials through deconstruction and salvage, in both cases diverting valuable materials from C&D landfills.

Reduction

Reducing the waste generated should be a top priority in sustainable waste management. The reduction option actually reduces the magnitude of the waste stream versus simply implementing more environmentally friendly ways of managing the existing waste stream. The key to reduction is designing for adaptability, longevity, and disassembly. This ensures that existing structures may be adapted for reuse or systematically disassembled, relocated or adapted, for component reuse.

Determine Regional Feasibility of Each Alternative

Once each waste reduction alternative is identified it is then necessary for a region to determine the alternative, or alternatives, most appropriate for implementation within a given region. The assessment tool was designed to fulfill two main purposes. First, the tool allows a user to define a region's potential for successful implementation of deconstruction as a waste reduction strategy. Second, based on scores generated from user entered regionally specific data the tool provides recommendation to the user regarding improving the regions' potential to successfully implement deconstruction. These scores can be used to determine if the region should pursue deconstruction as a waste reduction strategy or if the region should pursue other waste reduction alternatives.

Recommendations

One of the most important finding from this research study was the overall lack of coordination and collaboration between the National, State and regional level waste management organizations. The lack of a strategic plan driving the waste management/waste reduction process from the "top down" is a significant contributing factor to the absence of sustainable waste management implementation. The most important recommendation resulting from this research effort is to the development of a strategic waste reduction plan requiring the coordination of common waste management goals between the National, State and Regional waste management professionals.

Establishing a Strategic Plan

1. Develop a unified method of collecting C&D waste stream data: Unifying the C&D data collection methods is necessary to ensure that consistent and accurate data is available at the National, State, and regional level to correctly assess, evaluate, and project the C&D waste stream. Variation in the current data collection techniques used and the types of data that are collected make the current waste stream estimation and projections inaccurate.
2. Increase educational extension services: As solid waste mangers indicated, they are often unaware of innovative and sustainable waste reduction alternatives specific to the C&D waste streams. The qualifications of individuals making solid waste management decisions should also be evaluated. Solid waste managers can be required to earn continuing education units similar to contractors to assure that they stay current on innovative and sustainable waste reduction and management practices. On a local level, the state should mandate all demolition companies attend deconstruction seminars as part of the prequalification and the requalification process. Deconstruction

seminar attendance should also be required prior to the issuing of a demolition permit.

3. Establish improved coordination and collaborative efforts between National, State, and Regional waste management professionals: It was found that lower level (regional) solid waste managers were not actively pursuing alternative strategies to traditional waste management techniques while the upper level waste management professionals generally believed the solid waste managers were actively pursuing and continuously implementing new waste reduction strategies. The disconnection between waste management agencies must be addressed in order to optimize the waste management process.
4. Revaluate the C&D waste management decision making process: The existing C&D waste management decision making process may not allow for the implementation of innovative processes. Reviewing and revising the current decision making process to include allowances for innovative and sustainable alternatives to traditional waste management techniques.
5. Develop mandates, regulations, or requirements to increase the implementation of sustainable waste management practices: The solid waste managers who participated in this study indicated they were not actively pursuing alternatives since there were currently no requirements or incentives to do so. These regulations must govern both the public and private waste management sectors.
6. Establish a means of enforcing the established regulation: The current lack of initiative exemplified by some solid waste managers may indicate a resistance to implement sustainable disposal alternatives. If new processes are required, an evaluation system must be established to monitor the implementation progress.
7. Provide incentives for achieving waste reduction goals: Providing incentives to promote compliance with the strategic waste management plan may be necessary. Disincentives such as raising the cost of

demolition permits while issuing deconstruction permits at no cost should also be used. There are many incentive options for local and regional governments to explore.

Future Research Needs

Prior to this study there were no tools available to evaluate the deconstruction process as a regional waste reduction strategy. The development of the assessment tool resulted in several new research questions and possibilities for future expansion of the existing assessment tool. Recommendations for future research follow:

Assessment Tool

- Expansion: One of the most important future uses of this tool will result from combining it with structure specific deconstruction assessment tools currently under development. There are assessment tools being developed the UK, Germany, and at the University of Florida's Center for Construction and Environment that evaluate the potential for success of deconstructing an individual structure. These structure-specific assessment tools, once combined with the regional assessment tool developed in this research, will provide an excellent comprehensive tool for both contractors interested in pursuing individual unit deconstruction as well as solid waste professionals planning to implementing a region-wide waste reduction program. "This tool will compliment building specific auditing tools currently under development" (UK).
- Validation of Scoring System: Since the deconstruction process is not currently implemented as a waste reduction strategy it is necessary to pursue the validation of the assessment tool's scoring system as data becomes available. An analysis of each of the variables sensitivity and weighed impact on the success of the deconstruction process will assist in perfecting the current assessment tool scoring system and logic statements.

Deconstruction

- Further evaluate the cost effectiveness of deconstruction: Evaluating methods of increasing the cost effectiveness of deconstruction are needed to promote the acceptance of the deconstruction process. Research in the area of Designing for Disassembly, structures that are designed to be taken apart and reused, may assist in reducing the higher cost factor associated with the current deconstruction process.

True Environmental Costs

- Quantify environmental degradation: The true cost of environmental degradation as impacted by the C&D waste stream remains non-quantified. Current disposal costs are calculated without consideration for environmental impacts. This results in an apparent low cost of waste disposal. The low cost of current waste disposal practices acts as a deterrent to implementing alternative sustainable waste management practices. Until bases for factoring in environmental cost is established, these costs will continue to be disregarded by waste management professionals leaving mandates and incentives to provide the needed push toward sustainable waste management alternatives. Developing an accepted method of quantifying environmental impacts would assist regions in conducting full cost accounting of their waste management practices.

Education

- Evaluate the current educational requirements for Solid Waste Mangers: The question “Should there be a requirement for high level officials to attend environment sensitivity training?” should be investigated.
- Evaluate University requirements for basic environmental awareness educational courses: Begin exposing tomorrows professionals involved with the construction process to environmental issues prior to beginning their careers.

Summary

Through this research is was possible to achieve the overall goal of developing an assessment tool for use by solid waste professionals for use in determining a regions potential to successfully implement deconstruction as a waste reduction strategy. The research data and surveys indicate that the tool will play a fundamental role in deciding whether or not a region can support the deconstruction process. It is a recommendation that the summarized results of this work are distributed to National, State and regional agencies so that the regulatory agencies can better understand the need and potential for the implementation and acceptance of sustainable alternatives for reducing the C&D waste stream.

APPENDIX A

INFLUENCE FACTOR AND VARIABLE REFERENCES

The following is a list of references used to develop each of the following sections of the assessment tool.

Section 1 Regional Economics and Growth

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Section 2 Development Patterns

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Section 3 Business Infrastructure

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Section 4 Available Building Stock

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Section 5 Policy and Incentives

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Section 6 Waste Quantities
by dEsign, 1997; CIWMB, 1997; CCE, 1998; CCE, 2000; Fisbein, 1998; Hazen and Sawyer,1993; Joslin et al., 1993; Kreitner, 1996; Leroux and Seldman, 1999; NAHB, 1997; North Carolina Department of Environment, Health, and Natural Resources, 1993; Self-Reliance Inc., 1998; Reddrop and Ryan, 1997

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Greater Columbus Habitat for Humanity

APPENDIX C
SURVEY

Deconstruction Assessment Survey		
University of Florida Department of Civil Engineering PO Box 116580 Gainesville FL 32611	The University of Florida Department of Civil Engineering is conducting this survey on construction and demolition waste.	
Please Print the following information	If there are any questions please contact Jennifer Languell at jlangue@ulf.edu or 352 392 8173	
Person (s) reviewing assessment tool		
Contact information	Phone	
	Fax	
	e-mail	
Location	State	
	County	
	City/Town	
Indicate the following numbers from the Assessment tool	DIPS	
	Ranking	
	Waste reduction quantity	
	Waste reduction percentage	

Please circle the number best describing your response to the statement. Circle 1 for strongly agree with the statement, 2 agree, 3 neutral, 4 disagree, and 5 for strongly disagree.					
	Strongly Disagree				**Strongly** **Agree**
Construction and Demolition Waste is an insignificant portion of this regions waste stream	1	2	3	4	5
Deconstruction can affectively be used to divert demolition and renovation waste from landfills	1	2	3	4	5
The current administration is actively pursuing implementing innovative waste reduction strategies	1	2	3	4	5
If deconstruction would be feasible in the region, how effective is this assessment tool in the following areas					
1. The assessment tool will assist in selling a deconstruction program to the administration	1	2	3	4	5
2. The assessment tool is affective in identifying the needs of a deconstruction program	1	2	3	4	5
3. The assessment tool is affective in starting a deconstruction program	1	2	3	4	5
4. The assessment tool is affective in implementing a deconstruction program	1	2	3	4	5
The region has previously implemented waste reduction strategies	No				Yes
If yes, to what degree was the program successful?	Not Successful			Highly Successful	
	1	2	3	4	5
Please provide any additional comments regarding					
The assessment tool:					
Deconstruction:					

APPENDIX D
MAILING ENCLOSURES

April 5, 2001

Dear Sir or Madam:

As part of the research efforts at the University of Florida, enclosed you will find a Deconstruction Implementation Assessment Tool for your review. Deconstruction is a sustainable alternative to traditional demolition and disposal practices. As solid waste managers, the burden of successfully handling large quantities of the waste generated in the region is very important. Florida's population growth, the development needed to support the growth, and Florida's desire to become a more sustainable environment provides an excellent opportunity to pursue alternatives to traditional demolition.

Current research in the Department of Civil Engineering is concentrating on the process of deconstruction versus traditional demolition for wood frame residential structures. Part of the research required that an assessment tool be developed to determine the potential to successfully implement the deconstruction practice as an alternative to traditional demolition.

Enclosed you will find a CD. This CD contains a brief, 5 minute, narrated PowerPoint presentation that further defines the deconstruction process and provides instructions for the assessment tool. In addition to the presentation, the CD contains the Excel based assessment tool. The assessment tool contains macros that must be enabled for the tool to function correctly. Some user input is required after which, the assessment tool will calculate the regions Deconstruction Implementation Potential, Ranking, Potential Waste Diversion Quantity and Potential Waste diversion Percentage.

A survey completes this packet and will assist in adjusting the assessment tool for future use. Please record the regions DIPS, Ranking, Diversion Waste Quantity, and Diversion Waste Percentage. After completing the survey, please return the survey to the University of Florida in the enclosed envelope no later than April 25, 2001.

We thank you for your time and appreciate you efforts. Feel free to contact Jennifer Languell with any questions at jlangue@ufl.edu or 352 392 8173.

Regards,

Charles R. Glagola, Ph.D, P.E.

Assessment Tool Directions

1. Review 5 minute PowerPoint presentation

This presentation is available on the CD for both users with and without PowerPoint

If you have PowerPoint
Simply open the Presentation folder and click on the PowerPoint file entitled "Assessment tool Introduction"

If you do not have PowerPoint
Open the folder "Presentation if you do not have PowerPoint" and double click the file entitled PGNSETUP.exe. The computer will prompt you through the process to view the presentation.

2. Open Microsoft Excel

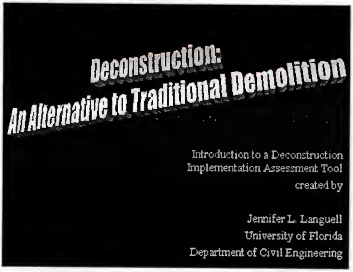
The assessment tool will not run without excel. The assessment tool will not run correctly without enabling the macros

3. The Excel file is entitled "Deconstruction Implementation Assessment Tool"

4. Read introduction and press gray button to begin using assessment tool

If there are any questions regarding the assessment tool please contact Jennifer Languell at jlangue@ufl.edu or 352 392 8173

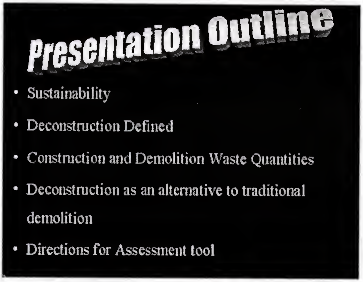
PRESENTATION



Deconstruction:
An Alternative to Traditional Demolition

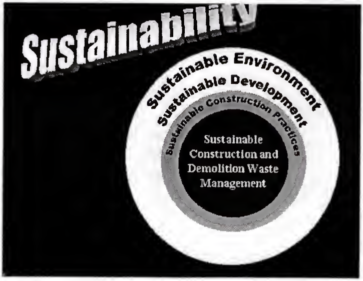
Introduction to a Deconstruction
Implementation Assessment Tool
created by

Jennifer L. Languell
University of Florida
Department of Civil Engineering



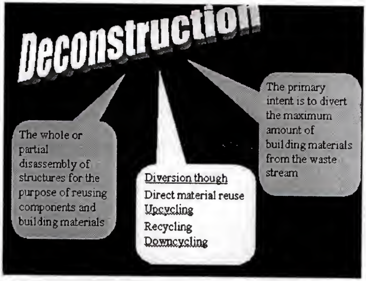
Presentation Outline

- Sustainability
- Deconstruction Defined
- Construction and Demolition Waste Quantities
- Deconstruction as an alternative to traditional demolition
- Directions for Assessment tool



Sustainability

Sustainable Environment
Sustainable Development
Sustainable Construction Practices
Sustainable Construction and Demolition Waste Management

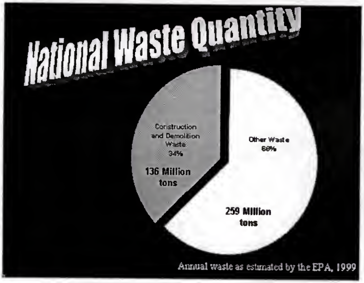


Deconstruction

The whole or partial disassembly of structures for the purpose of reusing components and building materials

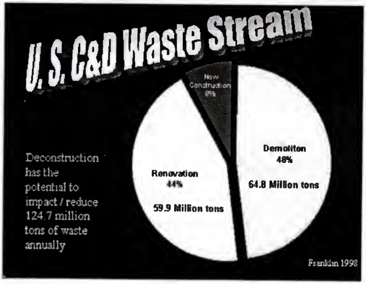
Diversion though
Direct material reuse
Upcycling
Recycling
Downcycling

The primary intent is to divert the maximum amount of building materials from the waste stream



National Waste Quantity

Annual waste as estimated by the EPA, 1999



U. S. C&D Waste Stream

Deconstruction has the potential to impact / reduce 124.7 million tons of waste annually

Franklin 1998

Why should we Deconstruct ?

Environment - Reuse materials
Conserve raw materials, reduce energy required for new materials, preserve landfill space

Region
- Employment Opportunities
- Encourage new businesses
- Provide low cost building materials
- Networks salvagers, builders, and reusers

Money
- Recycling revenues
- Reduce waste management expenses
- Tax income from new businesses
- Marketability of a "Green" region

Deconstruction Implementation Assessment Tool

- Not every region is perfectly suited to implement the deconstruction process
- Assessment tool was developed to determine the potential for the successful implementation of deconstruction in a given region
- Tool based on data from deconstruction case studies and physical deconstructions conducted by the University of Florida's Center for Construction and Environment

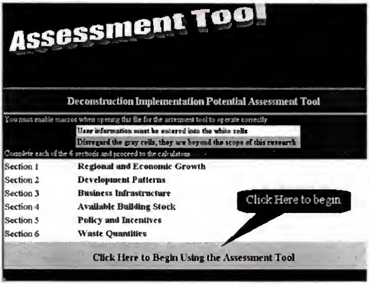
Deconstruction Implementation Assessment Tool

Based in Excel

Driven by macros

Requires user input

Provides the user with
1. Deconstruction Implementation Potential Score (DIPS)
2. Regional Ranking
3. Potential Waste Diversion Quantity
4. Potential Waste Diversion Percentage
5. Regional Evaluations



Assessment Tool

Deconstruction Implementation Potential Assessment Tool

You must enable macros when opening this file for the assessment tool to operate correctly

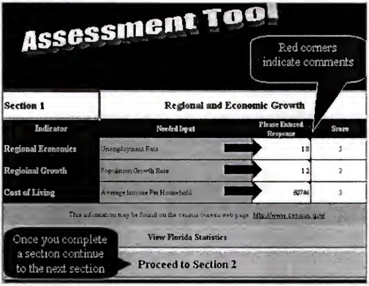
User information must be entered into the white cells

Disregard the gray cells, they are beyond the scope of this research

Complete each of the 6 sections and proceed to the calculations

Section 1	Regional and Economic Growth
Section 2	Development Patterns
Section 3	Business Infrastructure
Section 4	Available Building Stock
Section 5	Policy and Incentives
Section 6	Waste Quantities

Click Here to begin
Click Here to Begin Using the Assessment Tool



Assessment Tool

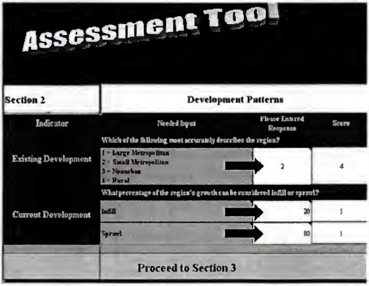
Red corners indicate comments

Section 1 Regional and Economic Growth

Indicator	Needed Input	Please Entered Response	Score
Regional Economics	Unemployment Rate	18	3
Regioinal Growth	Population Growth Rate	12	2
Cost of Living	Average Income Per Household	60746	3

This information may be found on the census bureau web page http://www.census.gov/

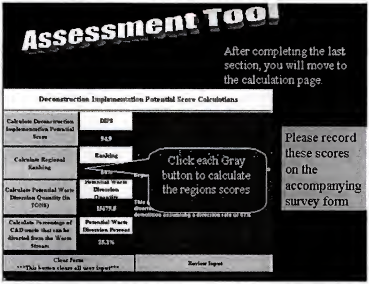
View Florida Statistics
Once you complete a section continue to the next section
Proceed to Section 2



Assessment Tool

Section 2 Development Patterns

Indicator	Needed Input	Please Entered Response	Score
	Which of the following most accurately describes the region?		
Existing Development	1 = Large Metropolitan 2 = Small Metropolitan 3 = Nonurban 4 = Rural	3	4
	What percentage of the region's growth can be considered infill or sprawl?		
Current Development	Infill	20	1
	Sprawl	80	1



Assessment Tool

After completing the last section, you will move to the calculation page.

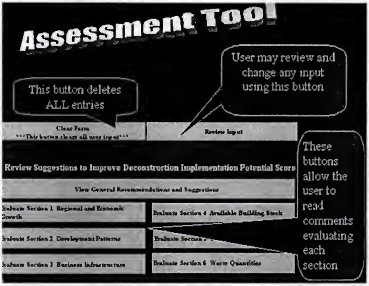
Deconstruction Implementation Potential Score Calculations

Calculate Deconstruction Implementation Potential Score	DIPS 94.9
Calculate Regional Ranking	Ranking 84%
Calculate Potential Waste Diversion Quantity (in TONS)	Potential Waste Diversion Quantity 15679.8
Calculate Percentage of C&D waste that can be diverted from the Waste Stream	Potential Waste Diversion Percent 25.3%
Clear Form ***This button clears all user input***	Review Input

demolition assuming a diversion rate of 67%

Click each Gray button to calculate the regions scores

Please record these scores on the accompanying survey form



Assessment Tool

User may review and change any input using this button

This button deletes ALL entries

Clear Form
This button clears all user input

Review Input

Review Suggestions to Improve Deconstruction Implementation Potential Score

View General Recommendations and Suggestions

Evaluate Section 1 Regional and Economic Growth

Evaluate Section 2 Development Patterns

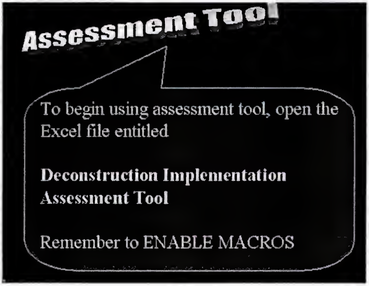
Evaluate Section 3 Business Infrastructure

Evaluate Section 4 Available Building Stock

Evaluate Section 5

Evaluate Section 6 Waste Quantities

These buttons allow the user to read comments evaluating each section



Assessment Tool

To begin using assessment tool, open the Excel file entitled

Deconstruction Implementation Assessment Tool

Remember to ENABLE MACROS

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BIOGRAPHICAL SKETCH

Jennifer Lynn Languell was born on August 15, 1972, in San Diego, California, to Dennis Lee and Carol Ann Languell. Jennifer's father was in the U.S. Navy, which ordinarily would result in relocation every two to three years. Due to great sacrifices on the part of her parents, often enduring months of separation in the best interest of their children, she had to relocate only three times. She moved from San Diego, California, to San Antonio, Texas, to Newport, Rhode Island, where she graduated from Rogers High School.

Jennifer received a Bachelor of Science degree in Materials Science and Engineering in 1995 and a Master of Engineering in civil engineering in 1997, both from he University of Florida. Upon the decision to pursue her Ph.D, she also began instructing an engineering economy senior level course in the civil engineering Department. She also worked for the M.E. Rinker, Sr., School of Building Construction's Center for Construction and Environment as a research associate and was an instructor for a building construction course in international sustainable development. Her three years as an instructor were some of the most fulfilling and personally satisfying years at the University. Jennifer married Scott R. Urquhart on April 15, 2000. After her graduation as a Doctor of Philosophy in civil engineering she will join ConstructGreen Inc., a Florida based consulting firm, as its Vice President of Consulting Services where she will be working in sustainable construction, her area of expertise.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Dr. Charles R. Glagola, Chairman
Associate Professor of Civil and
Coastal Engineering

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Paul Y Thompson

Dr. Paul Y. Thompson
Interim Associate Dean for Research and
Administration

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Dr. Zohar Herbsman
Associate Professor of Civil and
Coastal Engineering

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Ralph Ellis

Dr. Ralph Ellis
Associate Professor of Civil and
Coastal Engineering

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Dr. Charles J. Kibert
Building Construction

This dissertation was submitted to the Graduate Faculty of the College of Engineering and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 2001

Dean, College of Engineering
Dr. Pramod P. Khargonekar

Dean, Graduate School
Dr. Winfred M. Phillips